

BLM Study
Contract AA-852-CT5-29

FERTILITY CONTROL IN
WILD HORSES

FINAL REPORT

EDITED BY:
D.B. SINIFF and J.R. TESTER
University of Minnesota
Minneapolis, MN 55455

E.D. PLOTKA
Marshfield Medical Research Foundation, Inc.
Marshfield, Wisconsin 54449

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Chapter 1

OVERVIEW OF THE STUDY

D.B. SINIFF, J.R. TESTER
University of Minnesota, Minneapolis, MN 55455
E.D. PLOTKA
Marshfield Medical Research Foundation, Inc.

Introduction

In June 1985, the Bureau of Land Management issued solicitation AA852-RP5-27 which described three separate studies. We answered Part Three of this solicitation, entitled "Fertility Control in Wild Horse Populations". This solicitation was very detailed in study design. It specified that contraceptive experiments should focus on both mares and stallions and that contraception methods for mares would be tested in pen studies prior to being implemented on free-ranging individuals. Male sterilization would be tested using vasectomy of dominant band stallions and would be carried out on free-ranging individuals in two different study areas. The solicitation called for selecting three comparable areas in each of two states, thus, making a total of six study areas; two vasectomy areas, two mare experimental areas, and two mare control areas.

We attempted, in our answer to this solicitation, to fulfill the major study objectives and we provided detail as to how this would be accomplished. This report summarizes the results of studies initiated by the solicitation. In fulfilling the objectives, certain changes in study design were implemented as the study progressed. These changes were discussed with BLM and the National Academy Committee on Wild Horses and Burros, which initially developed the solicitation and review the proposals.

This report is composed of five summary papers. Other papers were published as the study progressed and will be cited in this report as appropriate. The summary papers of this report generally cover the results of the mare contraception work, the stallion vasectomy field studies, and results derived from modeling studies using data obtained from the Bureau of Land Management on horses gathered during herd reduction.

This study required that we handle a large number of animals to meet the sample size requirements outlined in the solicitation. The gatherings were handled through a contract with a professional roundup contractor recommended by BLM personnel in Nevada. Radio transmitters housed on collars with

numbers and numbered marker collars were attached to a large number of horses since it was required that individuals be relocated after treatment to check on reproductive performance. In the case of males, their status in the herd, and the overall reproductive performance of their band was required. A number of events occurred during the field work that tended to make the study controversial, and the controversy seemed to increase as the study progressed. Throughout the controversial periods, we tried to concentrate on the objectives of the research and attempted to fulfill the obligations we had to BLM and the National Academy of Science Committee under the contract. In general, we were successful in fulfilling these obligations, as the results in the following papers suggest. As controversies arose, they were generally investigated by either the National Academy Committee or BLM representatives; reports and/or communications were written to document findings and conclusions. These reports and communications are generally available, with the exception of a final report of the National Academy of Sciences Committee, which, to the best of our knowledge, is still pending.

Mare Studies

The mare contraceptive studies began with four objectives that were outlined in our original answer to the solicitation. These were: (1) to select and test an economical contraceptive method that could be administered in a single treatment to selected individual animals with a 90% efficiency over at least two full breeding seasons. (2) to develop or select a delivery system for the contraceptive treatment. (3) to assess possible adverse consequences of the contraceptive treatment and (4) to investigate the effectiveness of one or two promising treatments and/or delivery systems in field trials using mares in free-ranging bands. With these objectives before us, we began pen studies in the holding facility in Lovelock, Nevada.

Implantable silastic rubber rods impregnated with hormones were developed. Similar methods had been used successfully on humans and various species in zoos to prevent unwanted pregnancies, and it was felt that the method could be successful for horses. We began by testing various estrogen compounds in combination with progesterone. Initially, implants were placed in the necks of mares held at Lovelock. Blood was collected from 5 mares from each sample group approximately every two weeks to assay hormone levels and check the status of the implants. These initial implants proved successful with respect to suppressing estrus, but were judged unacceptable because many of the implants eventually fell out.

Thus, we considered other implant sites and, in consultation with veterinarians, placed several implants in the peritoneal cavity. Intraperitoneal implants were quick to administer,

recovery from the implantation surgery was nearly instantaneous, and we had no difficulty with infection. Because of the time pressure to complete the study on schedule, we used the neck implants on the mares in the first mare control area, (Wassuk Herd Management Area) before we were aware of the implant losses mentioned above. Once it was established that the intraperitoneal implants produced levels of hormone which prevented pregnancy, we continued in the field with intraperitoneal implants.

As mentioned above, in the original request for proposal it was suggested that two treatment and two control areas be used for the mare contraception work. We initiated this design by choosing Wassuk and Stone Cabin as the first mare control and experimental areas, respectively. However, after these areas were established it became obvious that there could be a significant area effect which might influence the overall reproductive rate of females. That is, if the habitat conditions were poor, reproductive rates would generally be low, and in such instances, the effect of contraception could not be separated from the effect of the environment. After the Wassuk and Stone Cabin phases were completed, it was decided that for the second treatment area, treatments and controls should be contained on the same area. Thus, for the mare contraception studies, three areas were finally established. These were: the Wassuk area, which has served as a control beginning in the spring of 1986, the Stone Cabin area where treatment was carried out in the late fall of 1986, the Clan Alpine area, completed in late 1987, where both control and experimental animals existed together. As mentioned above, in the Wassuks, implants were placed in the neck. The Stone Cabin and Clan Alpine implants were intraperitoneal.

The results summarizing the mare pen studies are given in Chapter 2 of this report. These results demonstrated that hormone implants were effective in suppressing reproduction for at least 2 years and provided preliminary data indicating effective contraception for 3 years. Furthermore, calculations based on serum concentrations of the contraceptive hormone suggested that the contraceptive could be effective for as long as 5 years.

Results of the free-ranging mare contraceptive studies are given in Chapter 3. We have data on the effectiveness of the contraception in the Stone Cabin area for three seasons, and data in the Clan Alpine area for only one season. Data were collected only in the Stone Cabin area in the final year of our research (spring 1990) because public and BLM pressure would not allow us to use helicopters to monitor reproduction. There was a perception by some BLM personnel as well as some public organizations that flying with helicopters to monitor foaling in the spring caused foal abandonment. While there were no

substantive data to support this contention, it was felt that our flight operations should be cancelled because of the negative publicity that was being generated. Therefore, in the spring of 1990 we concentrated on obtaining foaling rates for treated mares, from the ground, in the Stone Cabin study area. The Stone Cabin area was deemed the most important because this was the third year that the contraceptives would be effective for these mares. In addition, it would have been very difficult to work from the ground in the Clan Alpine area. Even though our obligation was to develop an effective contraceptive device for two years, the added bonus of obtaining data to measure effectiveness for three years was obvious.

The Clan Alpine site was the last area where we gathered horses for treatment. This was carried out in late August and early September of 1987. This area had been gathered by the Bureau of Land Management approximately a month earlier and they planned to leave a sufficient number of animals to satisfy the sample size requirements that were outlined in the original solicitation. However, as the gathering for treatment proceeded, we were informed that there were insufficient animals to meet our requirements. The Bureau of Land Management representative present during the gathering suggested to us that animals from the Clan Alpine moved to and from an adjacent area and sufficient animals to satisfy our requirements could be brought through gaps in a fence separating the two areas. We agreed to this arrangement and the necessary animals were gathered. Those in the appropriate sex/age categories were treated with contraceptive implants or placebos as appropriate, and released. These animals were released with the assumption that they would return to their area through the reported gaps in the fence. Unfortunately, this did not happen and 48 of the animals died along the fence. This incident created considerable controversy, which was investigated by BLM and the National Academy Committee on Wild Horses and Burros. Although a report on the investigation was written by the Bureau of Land Management, the NAS Committee report is still forthcoming. This incident, to a large degree, tainted the rest of our studies and focused national attention on the project.

This incident was indeed unfortunate, both because of the loss of the animals and because it created issues which were not related to the overall scope and results of the study. It did not interfere significantly with the results we obtained, nor with the predictions that have been derived from our findings. The NAS report should help to clarify the influence of this event on our results so that the use of mare contraception for controlling growth rates of wild horse herds can be viewed in the proper scientific light.

Stallion Vasectomy Studies

Chapter 4 of this report summarizes the vasectomy studies on the Flanigan Study area north of Reno, Nevada and the Beatty Butte study area in eastern Oregon. In each area, 20 bands of horses were gathered individually. The dominant stallion in each band was vasectomized and the entire band was returned to the free-ranging population. Radio transmitters were attached to the vasectomized stallions. We attempted to follow the bands through the reproductive seasons to assess the effectiveness of the vasectomies. This study became difficult because when the stallions fought, they often used the collars as the focus of their battles. Collars were frequently torn off in these encounters. Therefore, we could not radio track several of the vasectomized stallions. However, we obtained some data from ground observations relying on physical characteristics for identification. As a result, our sample sizes for the vasectomy studies are small.

In the Flanigan area, an investigator spent a good deal of time walking through the area observing band structures with and without vasectomized stallions. As paper three suggests, we obtained some data in this way, but complications occurred because animals were lost and there were switches in band membership and structure. Regardless, the data we obtained, we feel, depicts the likely result of using male sterilization to control population growth rates.

Chapter 5 of this report discusses a modeling exercise which explores the effects of the presence of vasectomized stallions on annual reproductive patterns. Since horses are polyestrous, they will cycle several times during the summer if the postpartum mating is not successful. The presence of a vasectomized dominant stallion would likely cause the female to cycle many times through the summer until successful breeding from a fertile male occurs, or the reproductive season ends in the fall. We have predicted that these effects could be significant and need to be considered if male sterilization in seasonally breeding animals is to be used to control population growth rates.

Some Management Consequences of the Application of Mare Contraception

The final chapter of the report uses population data obtained from the horses gathered for herd reductions by the Bureau of Land Management over the past 15 years. Over 60,000 records on age structure and reproductive condition of individual animals were obtained from various Bureau of Land Management offices. In addition, detailed data from the Pryor Mountain wild horse range were also valuable in this effort. Further, annual census data obtained by BLM were also available on many herd

areas. These data were used to obtain estimates of population growth rates of various horse herds. The results of the analyses of all these data provided the foundation for a population model that was used to predict the consequences of various management options, including the use of mare contraception. Data on the cost of various management procedures which had been previously used by BLM were contrasted to the costs of the contraceptive techniques used in our studies. Because of the quality of the data used in the simulations, it seems likely that the predictions found in this paper are very close to the actual results that one could expect if the contraception program were to be applied to wild horse herds. As this paper shows, contraception is not a panacea that solves all of the problems, but would contribute to slowing the growth rates and lessening the problem of the number of horses that need to be removed to achieve herd management goals.

Conclusion

The papers of this report give details and results of our research efforts for mares and stallions. When this work was initiated, the National Academy Committee and others obviously envisioned that these procedures would contribute greatly to controlling growth rates of wild horse herds in the West, and would be widely accepted by concerned conservation groups. Although our studies were controversial because of various incidences and procedures, there are important general conclusions which should have significant influence on future management decisions.

The mare studies demonstrated that we can significantly slow the growth rate of the herds by implanting slow release hormones in a significant fraction of the prime age mares. The success we had in extending contraception into the third year makes the predictions in the final paper of this report very realistic. In applying mare contraception techniques our data and simulations show that a large proportion (at least 80%) of the prime age mares (ages 4 through 12) may need to be treated approximately every three years for the herd growth rates to be significantly depressed. We have shown this procedure to be cost effective as compared to the other management procedures which are available for wild horse herds. Mare contraception, as developed within our research, could be used to develop long-term management plans, where the number of animals on a given herd range could be managed closely. As a result, population dynamics would be relatively predictable over the long term. Management plans could be written so that procedures could be implemented on a specific schedule which could be projected into the future. In this way, public scrutiny of future plans would be possible for several years in advance of the actual management manipulations.

Mare contraception significantly reduces the overall number

of animals that need to be taken into captivity to maintain herd management goals. As we have outlined in Chapter 6, the combination of gathering younger animals, which are adoptable, and using mare contraception greatly limits the number of individuals that need to be taken from the wild to maintain a herd management area at a given population level.

The problems which were encountered during our research efforts were, in general, independent of any application for maintaining herd management goals. That is, the implementation of these procedures need not follow the procedures that we used during our research. We were constrained because of guidelines in the original solicitation, and because of the requirement to keep track of individual animals during the period of study. The two most controversial procedures, collaring horses and spring helicopter surveys, would not be necessary when applying mare contraceptives as a management procedure. Future management options need to be fully discussed in the light of our findings and in the light of what the Bureau of Land Management might require as long-term management goals.

Chapters 4 and 5 on male sterilization, we feel, depict rather precisely what future implementation of this approach would produce in terms of contraception. Sterilization of dominant stallions has some influence on foaling, particularly in bands where the sterilized stallion remains dominant. However, the degree of suppression of the overall growth rate of the herd is complicated and unpredictable because it depends upon the stability of the bands which make up the population. The more potential for turnover that exists, the more unsuccessful this approach is likely to be. Chapter 5 indicates that male sterilization would have a significant influence on changing the seasonal pattern of foaling. Since mares have a gestation period of slightly less than one year, and since they will continue to go through estrus cycles if not bred following parturition, there will be a tendency for individual mares to foal later and later in the summer. This tendency, of course, would be detrimental, since foals born late in the summer would be at greater risk for surviving the winter. This tendency for increased foal winter mortality would be more pronounced at high altitudes and in the more northern herd areas.

Recently, Kirkpatrick et al. (1990) provided information on a technique using immunocontraception, with a treatment that is remotely delivered. Since the idea of remotely delivering contraception to wild animals seems to be of widespread interest, both in the research literature and by concerned conservation groups, we feel that it is appropriate that we should comment on this option. In Kirkpatrick et al. it is suggested that a minimum of two inoculations are required for this method to be effective for a maximum of one year. This paper also suggests that the technique is a significant improvement over other

contraceptive methods because it can be remotely delivered.

We believe that immunocontraception may be a useful tool for small horse herds, where individuals can be approached easily and where individuals are recognizable from physical markings. Here the probability of injecting the same animal twice within a short period of time might be quite high. Also, if the animals are accustomed to being approached, it would be possible to move among them and select individuals which had been previously missed. However, we feel that applying these techniques to most wild horse herds, particularly in Nevada, would be virtually impossible. These herds are often large (from 700 to 1000 individuals), and the horses are extremely wild when approached either from the ground or the air. It is usually impossible to approach closer than a few hundred yards before they start moving away. Further, it is often difficult to quickly identify individuals based on natural markings because of uniform characteristics in many herds. Thus, it seems to us that for most herd areas, approaches from the ground or from helicopters with remote delivery equipment would be unsuccessful in injecting a large number of animals twice within a short period of time. It appears that the only way for this procedure to be effective would be to gather the animals and inject them as they pass through chutes, similarly to what we have done for the hormone implant. However, for this technique the horses would need to be handled much more frequently than would be necessary using hormone implants. In general, we believe that immunocontraception is a useful technique. However, we feel that the methodology proposed for delivery and the frequency of treatment required (Kirkpatrick *et al.* 1990) would not be successful for controlling population growth rates in horse herds, such as currently exist in Nevada.

In summary, we were successful in complying with the charge of BLM and the NAS Committee on Wild Horses and Burros, and developed a mare contraceptive that is 90% effective for longer than 2 years. This contraceptive, when field tested, significantly reduced foaling rates as compared to control herds. In the future, careful deliberation examining how these procedures might be implemented in a management program, and contrasting these results with other methods, would seem to be important steps to the solution of conflicts involving wild horse herds on the public lands of western United States.

Acknowledgements

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cooperation of Fred Wyatt, Manager of BLM's Palomino Valley Wild Horse and Burro Placement Center in Sparks, Nevada, in providing records on tens of thousands of horses which had been processed at the Center was very much appreciated. BLM personnel who were particularly supportive and helpful with various aspects of our studies were Roger Bryan, Tim Reuwsaat, Lynne Taylor, and Jack Steinbreck.

Personnel of the Nevada Nile Ranch assisted in handling and bleeding horses maintained at the Lovelock, Nevada holding facilities. We are also grateful to the crews of High Desert Helicopters and Helicopter Roundup Services for their experience and expertise during the capture and handling of the large number of horses needed for this study as well as their piloting skills during aerial survey and darting operations. A. Rodomerg, S.J. Gaulke, A.L. Koller, G.C. Schmoller, D.N. Vevea, and F. Zarembka assisted in the fabrication of the hormone implants and the various blood assay procedures required. S. Broste helped in analysis of the blood data, and Stargardt provided editorial assistance.

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Literature Cited

Kirkpatrick, J.F., Liu, I.-K.M. and Turner, J.W., Jr. 1990. Remotely-delivered immunocontraception in feral horses. Wildlife Soc. Bull. 18:326-330.

Chapter 2

HORMONAL CONTRACEPTION OF WILD MARES WITH SILASTIC RODS

E.D. PLOTKA and D.N. VEVEA
Marshfield Medical Research Foundation, Inc.
Marshfield, WI 54489

and
T.C. EAGLE, J.R. TESTER and D.B. SINIFF
University of Minnesota, Minneapolis, MN 55455

Abstract

Homogeneous Silastic rods containing ethinylestradiol (EE, 1.5 or 4g), estradiol-17 β (E, 4g) or progesterone (P, 6g) were implanted into wild mares, which had been removed from the open range and were held at Lovelock, Nevada, between 4 and 10 years old. The six treatment groups (≥ 10 mares/group) of open mares received either 36g P and 12g E (P+E), 36g P and 8g EE (P+High EE), 1.5g EE (Low EE), 3g EE (Medium EE) or 8g EE (HEE). Two groups of pregnant mares received P+HEE or HEE. Control mares (CI) received implants containing no steroid. Stallions were placed with the mares 15 to 26 months after implanting. Blood was collected biweekly for up to 28 months after implanting and serum analyzed for P by radioimmunoassay. A single P value ≥ 2.5 ng/ml indicated ovulation and 2 consecutive values ≥ 2.5 ng/ml indicated pregnancy. Serum from blood collected before and at 4, 12, 24, 50, 64 and 89 weeks after implanting was analyzed for EE concentrations.

All animals pregnant at the time of contraceptive placement delivered normal foals. Contraceptive efficacy for groups LEE, MEE, HEE and P+HEE were 75, 75, 100, and 100 percent respectively after 2 breeding seasons. Suppression of ovulation appeared to be inversely related to the concentration of EE used in the implant. The percent of animals ovulating after 2 years of contraception in each group was 100, 88, 62, 20, and 12 for groups CI, P+E, LEE, MEE, HEE and P+HEE, respectively. The pregnancy rate for the same groups was 100, 25, 25, 0 and 0 percent, respectively. Contraceptive efficacy was followed for 3 years in one group, P+HEE, and was 88 percent. Pregnancy rates for groups P+E and CI after 3 years was 78 and 82 percent, respectively. Our data demonstrate effective contraception of wild mares for up to 36 months without compromising the pregnancy in effect at the time of implanting. Based on the decline in EE concentrations to 150 percent of pre-implantation concentrations, these data suggest an effective contraceptive life of approximately 16, 26, and 48-60 months for LEE, MEE and HEE implants, respectively. Mechanisms that appear to be involved

include preventing ovulation for higher concentrations of steroids and either suppressing ovulation or implantation for lower concentrations of steroids.

Introduction

Management of feral and wild populations of animals to prevent habitat destruction and crop damage in the United States is a controversial subject due to the many special interest groups involved in the decisions about management. For wild horses (*Equus caballus*) the problem of overgrazing of public rangelands is particularly controversial because, although designation of rangelands as overgrazed has not been experimentally substantiated (Vale, 1975; Wagner, 1983; Berger, 1986), such categorization is common among stockmen, wildlife specialists and some environmentalists. Livestock interests continue to complain about grazing competition between livestock and wild horses, and management policies of the Bureau of Land Management (BLM) often have favored these interests, primarily because grazing has been the most important commercial activity on public lands in the western United States (Wagner et al., Vale, 1975).

Appropriate management levels of horse numbers have been set for rangelands (Boyles, 1986), and since 1978 substantial sums of money have been appropriated to BLM for the removal of horses to achieve these management levels. The number of horses removed in recent years has at times been greater than the number adopted, and permanent confinement facilities have been established. To reduce costs, the BLM began investigating the potential for reducing the recruitment rate of free-roaming populations of horses by limiting reproduction.

In an earlier report, we presented our experience with estradiol-17 β (E) and/or progesterone (P) impregnated Silastic rods for controlling estrus, ovulation and pregnancy in captive wild mares at one of BLM's permanent confinement facilities (Plotka et al., 1988). Neither P (24g) alone, E (8g) alone nor combinations of the two (up to 8g each) prevented ovulation and conception. This paper presents a continuation of these studies using higher dose levels of hormone.

Materials and Methods

Silastic rods (implants) were prepared in lots of 20 as described previously (Plotka et al., 1988). Briefly, either crystalline P (4g/implant; Steraloids, Inc., Wilton, New Hampshire 03086, USA), crystalline E (4g/implant; Sigma Chemical Co., St. Louis, Missouri 63160, USA) or crystalline ethinylestradiol (EE) (1.5 or 4g/implant, Steraloids, Inc., Wilton, New Hampshire 03086, USA) was thoroughly mixed with silicone rubber (Silastic #382, Dow Corning, Inc., Hemlock,

Michigan 48626, USA). Control implants consisted of silicone rubber without steroid. Following addition of catalyst, the mixture was drawn into either 3 cc (1.5g) or 12 cc (4g) disposable syringes and allowed to cure for 10 to 24 hr. After curing, the syringes were removed and implants were soaked in sterile saline (0.9 percent) for a minimum of 24 (usually 72) hr. The saline bath was changed every 24 hr.

The wild mares used in the study were captured during the first six months of 1985 and after initial processing were confined at the BLM's Wild Horse Holding Facility in Lovelock, Nevada 89419, USA (40°11'N, 118°23'W). Mares were aged according to tooth wear (Ensminger, 1969) by BLM personnel and ranged between 4 to 9 yr of age. They were housed in 30 x 30 m pens at a maximum density of 50 per pen, fed a ration of chopped alfalfa hay and straw twice daily, and allowed water ad libitum. Maintenance and veterinary care were provided by personnel at the facility under a contract with the BLM.

Mares were palpated to ensure each was open in September 1985. Pregnant mares were palpated to ensure viable pregnancy during September 1986. Control mares were implanted in November 1985 with the implants placed subcutaneously in the neck as a part of a previous study (Plotka et al., 1988). One group of 10 treated mares was implanted in April 1986. Five of these mares received implants intramuscularly and 5 received implants subcutaneously. The remainder of the mares were implanted in the peritoneum in January 1987. The procedure for preparing the site for implant placement was the same for all groups. After a mare was immobilized, a 10 x 10 cm area of hair was clipped from the left flank and the area scrubbed with Betadine solution (The Purdue Frederick Company, Norwalk, Connecticut 06856, USA). Six cc of 2 percent lidocaine solution (Vedco Inc., Overland Park, Kansas 66204, USA) was injected intradermally and subcutaneously as a local anesthetic and a 30 to 35 mm incision was made through the skin. A stainless steel trochar with stainless steel sleeve large enough to fit over the implants was used to penetrate the muscle and tissue surrounding the peritoneum. After removal of the trochar, the implants were inserted into the peritoneal cavity through the sleeve. The sleeve was removed, and the incision closed with one mattress suture using 2-0 chromic catgut suture. All animals received 10.5×10^6 IU benzathine penicillin (Plocillin, Bristol Laboratories, Syracuse, New York 13201, USA) intramuscularly following the procedure. Necropsy of mares that died from unrelated causes during the study showed that, on a few occasions, the peritoneum was not entered and the implants were in the fat adjacent to the peritoneum wall. The procedure for placing implants subcutaneously in the flank or in the muscle was the same except for the location and that 12 to 15 cc of lidocaine was used to anesthetize a larger area.

Six groups of open mares and two groups of pregnant mares

were implanted (Table 1). The appropriate amount of hormone implanted into each mare was achieved by varying the number of implants. Stallions were placed in with the mares in April 1988.

Table 1. Hormone amounts implanted in each treatment group of wild mares.

Group	Progesterone (g)	Estradiol-17 β (g)	Ethinylestradiol (g)
P+E	36	12	0
P+HighEE	36	0	8
LowEE	0	0	1.5
MediumEE	0	0	3
HighEE	0	0	8
Control	0	0	0

Blood was collected from all mares every two weeks during the breeding season (April through October) and monthly during the anestrus season (November through March). The bleeding procedure consisted of restraining the mare in a squeeze chute and puncturing the jugular vein with a 15 ga needle attached to a 35 ml syringe. Two to 5 ml of blood was immediately transferred to a vacuum tube containing Na EDTA for hematological analyses; the remainder was transferred to plain vacuum tubes and allowed to clot for 4 to 12 hr. The clotted blood tubes were then centrifuged, and the serum was decanted and frozen until assayed for levels of P or EE.

P concentrations were determined by radioimmunoassay using a commercial radioimmunoassay kit (Diagnostic Products Corporation, Los Angeles, California 90045, USA) as previously described (Plotka et al., 1988). Serum EE concentrations were determined by radioimmunoassay utilizing a highly specific anti-EE antiserum. The antiserum was raised in rabbits by making an initial intradermal multiple-site injection of 50 μ g of 1,3,5(10)-estratrien-17-ethinyl-3,17 β -diol-6-one 6CMO:BSA (Steraloids, Inc. Wilton, New Hampshire 03086, USA) conjugate in 3:1 v/v Freund's complete adjuvant:0.9 percent NaCl (w/v in H₂O) containing an additional 20 mg attenuated Mycobacterium tuberculosis (Difco Laboratories, Detroit, Michigan 48233, USA). The rabbits also received a second injection of 0.1 ml DPT vaccine subcutaneously. Subsequent boosting occurred at 1, 2, 4, and 7 months with 100-150 μ g conjugate in 1:1 Freund's incomplete adjuvant:0.9 percent NaCl. One half of this emulsion was injected intramuscularly and the remainder subcutaneously. The rabbits were bled monthly by vacuum suction from a cut in the lateral ear vein. The blood was allowed to clot 2 hr at room temperature and centrifuged. The serum was stored at or below -

15°C until tested for immunoreactivity with EE2 (Steraloids, Wilton, New Hampshire 03086, USA). Serum P5-041089 was characterized and utilized in the assay.

One ml of horse serum was extracted with methylene chloride and the extract dried and concentrated in the bottom of a 12x75 glass tube. The dried extract was taken up in 1.0 ml of assay buffer (0.1M PBS, 0.1 percent sodium azide, pH 7.0, with 0.1 percent w/v gelatin) and incubated with intermittent vortexing for 1 hr at room temperature prior to assay. For the assay, parallel dilutions of samples taken up in buffer were made to 0.5 ml and compared with a standard curve of 250-1.95 pg/tube in 0.5 ml assay buffer. Assay buffer (0.1 ml) containing 4600 cpm 6,7 3H-EE2 (NEN Research Products, Boston, Massachusetts 02118, USA) with a specific activity of 59.2 Ci/mmol was added to all tubes. One tenth ml of our rabbit P5-890410 antisera diluted 1:900 in assay buffer was then added to all tubes (except total count and non-specific binding tubes) for a final antisera dilution at incubation volume of 1:3600. The assay was incubated for 15-20 hr at 4°C and separation of bound from free carried out by addition of 0.4 ml of 0.1M PBS (no gelatin) containing 0.02 percent dextran and 0.2 percent w/v activated charcoal. One half ml of supernatant was counted in a liquid scintillation counter. This assay is specific for EE with <0.15 percent cross-reaction with known horse estrogens. Sensitivity of the assay is 10 pg with a coefficient of variation of 18 percent at sensitivity.

Data are presented as means $\pm$ standard error throughout. Differences were determined by Fishers exact test utilizing the Number Cruncher Statistical Program written by Dr. Jerry Hintze (Kaysville, Utah 84307, USA).

Results

Some mares from each group died during the course of the study. All deaths were attributable to problems related to handling of these undomesticated, wild mares in captivity. Each group had a minimum of 8 mares at the end of the study. During the first year after treatment, some mares in all groups, except the P+HEE, appeared to have ovulated (Table 2) based on serum P concentrations ≥ 2.5 ng/ml. During the second breeding season after treatment, a percentage of all groups ovulated (Table 3). However, only 2 of 8 mares in each of the LEE and MEE groups became pregnant (Table 4). None of the mares in the HEE or P+HEE groups became pregnant (Table 4). Differences between treated and control mares for numbers ovulating and numbers becoming pregnant were highly significant ($P < 0.001$).

Table 2. Ovarian function in captive wild mares receiving contraceptive implants during the first year of contraception

Group	Number tested	Number ovulating	Percent ovulating	P*
P+E	11	2	18	<0.0001
P+HighEE	19	0	0	<0.0001
LowEE	8	4	50	<0.01
MediumEE	8	4	50	<0.01
HighEE	20	1	5	<0.0001 [§]
Control	24	23	96	

All comparisons made against the control group.

Table 3. Ovarian function in captive wild mares receiving contraceptive implants during the second year of contraception

Group	Number tested	Number ovulating	Percent ovulating	P*
P+E	11	11	100	NS
P+HighEE	16	2	12	<0.0001
LowEE	8	7	88	NS
MediumEE	8	5	62	0.02
HighEE	20	4	20	<0.0001
Control	18	18	100	

All comparisons made against the control group.

Table 4. Pregnancy rate of captive wild mares receiving contraceptive implants after 2 years of contraception

Group	Number tested	Number pregnant	Percent pregnant	P*
P+E	--	--	NT [§]	--
P+HighEE	16	0	0	0.001
LowEE	8	2	25	0.06
MediumEE	8	2	25	0.06
HighEE	20	0	0	<0.001
Control	3	3	100	

All comparisons made against the control group.

[§]Not tested.

Serum EE concentrations were highest 1 month after implanting and exhibited a log-linear decline over time. Although not directly proportional, serum concentrations reflected the amount of EE implanted (Figure 1). Serum EE concentrations increased from 11 ± 2 pg/ml before implanting to 46 ± 7 , 79 ± 7 , and 417 ± 64 pg/ml in open mares receiving LEE, MEE, or HEE, respectively and to 291 ± 29 pg/ml in pregnant mares receiving HEE. No difference was observed between peak EE values in open or pregnant mares receiving HEE ($P > 0.10$). Open and pregnant mares receiving P+HEE achieved serum concentrations of EE of 320 ± 68 pg/ml and 277 ± 17 , respectively ($P > 0.10$). Serum EE concentrations at 89 weeks after implanting averaged 14 ± 2 , 18 ± 2 , 56 ± 5 and 60 ± 8 pg/ml for the LEE, MEE, HEE and P+HEE groups, respectively. Efficacy of contraception through 89 weeks (2 breeding seasons) was 75, 75, 100, and 100 percent for the 4 groups.

The P+HEE group implanted in April 1986 was followed through a third breeding season. One of the eight mares remaining in that group became pregnant during that breeding season (Table 5). Serum EE concentrations dropped from 80 pg/ml to <10 pg/ml during the 1986 breeding season (Figure 2). Since the implants were placed intramuscularly in this animal, the rapid drop in serum EE would indicate that the implants had been lost. A second mare also had a precipitous drop in serum EE concentrations at the same time but did not become pregnant. Serum EE concentrations in the six remaining mares in that group averaged 35 ± 4 pg/ml 30 months after implanting (Figure 2).

Table 5. Pregnancy rate of captive wild mares receiving contraceptive implants after 3 years of contraception.

Group	Number tested	Number pregnant	Percent pregnant	P
P+E	9	7	78	NS
P+HighEE	8	1	12	0.002
Control	17	14	82	

All comparisons made against the control group.

We calculated the time for serum EE2 concentrations to decline to 150 percent of pre-implantation concentrations utilizing the regression calculated from the EE values obtained from bleedings more than 6 months after implanting. The data suggest an effective contraceptive life of approximately 16, 26, and 48-60 months for the 1.5g, 3.0g and 8.0g implants, respectively. The addition of P to the HEE did not lengthen the

Figure 1. Concentrations of serum ethinylestradiol (EE) in mares over 21 months after being implanted with Silastic rods containing 1.5, 3.0, or 8.0g of EE. All implants were placed into the peritoneal cavity (see text for details).

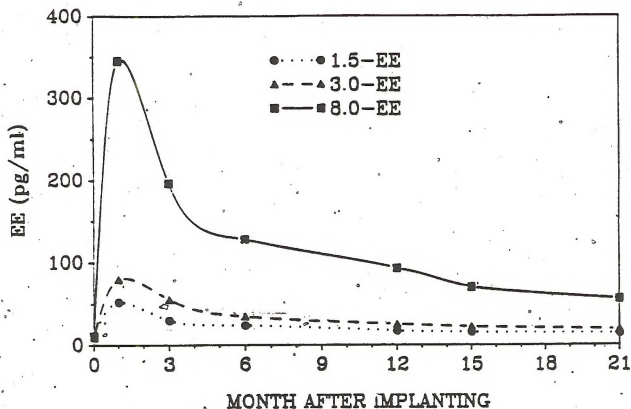
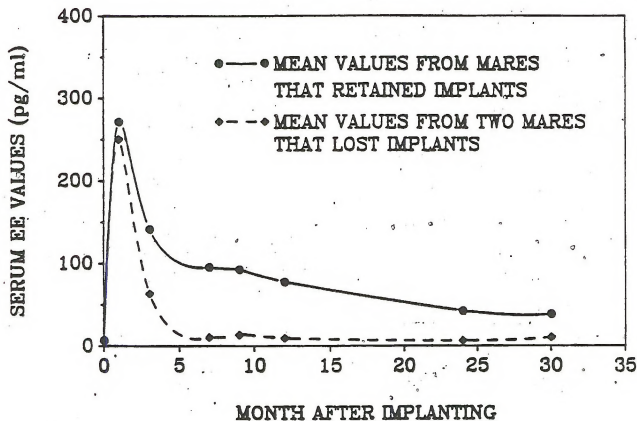


Figure 2. Serum concentrations of ethinylestradiol (EE) in mares retaining implants and 2 mares that lost implants over 30 months after receiving 8.0g EE.



effective life of the implants.

Discussion

The primary objective of this study was to develop an effective method for preventing reproduction in wild, free-roaming horses for a period of at least 2 years. Silastic rods were chosen as the vehicle for delivering the hormone because after an initial surge and equilibration, release of hormone was uniform over time (Figure 1). Our data demonstrate that Silastic implants containing 8.0 g of EE effectively accomplished this goal in captive animals. The type of release curves exhibited by Silastic rods and the ability to make implants that contain enough hormone to inhibit reproduction for extended periods of >2 years allows use of these implants in free-roaming animals. Studies recently finished have demonstrated 90 percent efficacy of both P+HEE and HEE in free-roaming wild mares (Eagle et al., 1990, this report). Hormone implants appear to be the only method presently available for effecting contraception for long time periods without repeated treatment.

Implantable contraceptive preparations have been used in captive, wild species for several years. The first attempts at implantable contraception of non-domestic species came concurrently from independent studies of Bell and Peterle (1975) with white-tailed deer and Seal et al. (1975) with lions, tigers, jaguars and leopards. Since then, only a few studies have been published and most of these are with captive animals and were only in use for short periods. Seal, however, has used melengestrol acetate in Silastic implants for several years in various species of primates and felids (personal communication). In addition, Silastic capsules of levonorgestrel have successfully prevented reproduction for up to 5 years in humans (Holma, 1985).

In order to determine the length of time the contraceptives would be effective, we set up an assay for EE. This allowed us to determine the amount of hormone in animals sequentially over time. Serum EE reflected a rapid release of hormone from the implant to peak serum concentrations by 60 days after implanting. Release dropped off quickly until reaching equilibrium by about 6 weeks. Release then slowed and was linear through the 21st month (Figure 1). Utilizing the fact that the LEE group had a 75 percent efficacy of contraception after two breeding seasons with serum EE concentrations averaging 14 ± 2 pg/ml, this level could be considered as the minimal serum concentration of EE needed for effective contraception. Calculating the length of time for serum EE concentrations in the HEE groups to decline to 15 pg/ml (150 percent of background), the effective life of contraception in these groups is between 48 and 60 months.

As far as we are aware, this is the first demonstration of long term contraception of an equid species. Kirkpatrick et al., (1982) reported that a microencapsulated form of testosterone propionate administered to the only sexually mature stallion in a band of free-roaming wild horses successfully suppressed reproduction without altering behavior. Although this study reported efficacy, the fact that there was only a single mature stallion in the treated bands leaves one with the question of how effective this treatment would be in bands where multiple sexually mature stallions were present and whether all stallions would have to be treated.

More recently, Kirkpatrick et al. (1990) reported successful contraception of wild horses after immunization of the mares with porcine zona pellucida. The protocol required at least 2 (3 was preferred) injections over a 3 to 4 month period before contraception was achieved. In addition, the adjuvant that was added to the vaccine to enhance the immune response generated an undesirable reaction at the injection site of some animals. One major disadvantage of this procedure is the need to identify and reinject individuals up to 3 times.

One of the disadvantages of any contraceptive procedure for free-roaming species is the cost and effort involved in effectively administering the contraceptive agent. The cheapest and least labor intensive method of delivering a contraceptive is to place it in a palatable feed that could be put out for the animals. However, past attempts at oral administration of contraceptives to several species have met with only partial success (Kirkpatrick and Turner, 1985). A significant shortcoming of oral administration is that it results in immediate high hormone levels that decrease with time, and repetitive doses must be given at frequent intervals to keep the hormone levels in an effective range. Injectable contraceptives are longer acting and would be more applicable for free-roaming animals. However, as mentioned above, currently available injectable contraceptives require reinjection of the animals at frequent (monthly or quarterly) intervals.

The studies reported here have demonstrated that implants containing EE are effective for at least 3 years and suggest efficacy for up to 5 years. The major disadvantage of our procedure is the need for catching the mares for delivery of the implants. The cost of rounding up and handling the large numbers of animals necessary to effect population control significantly increases the cost of implementation of a contraception program. However, as Garrott (1990) has shown, the cost is significantly less than the BLM's current program of periodic removal of excess horses.

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Chapter 3

EFFICACY OF A MARE CONTRACEPTIVE DEVICE IN FREE-RANGING HORSES

T.C. EAGLE, R.A. GARROTT, D.B. SINIFF, J.R. TESTER,
University of Minnesota, Minneapolis, MN 55455
and

E.D. PLOTKA
Marshfield Medical Foundation, Marshfield, WI 54449

Abstract

A study of fertility control in wild horses (*Equus caballus*) was conducted in 3 study areas in Nevada from 1986-1989. A total of 291 mares were implanted with silastic rods containing no hormone, 8 g ethinylestradiol, or 8 g ethinylestradiol with 36 g progesterone to test the efficacy of hormonal control of reproduction in horses. Foaling rates were reduced from about 50% in control mares to about 10% in treated mares for at least 2 years. Annual survival of treated and control mares was at least 95%, which suggests that hormone treatments did not affect mare survival.

Introduction

Congress protected wild horses on western rangelands and delegated responsibility for their management to the Bureau of Land Management (BLM) and the U. S. Forest Service with passage of the Wild Free-Roaming Horse and Burro Act of 1971. Of the nearly 40,000 wild horses occupying public rangelands in the western United States, about 38,000 (95%) are found on lands administered by BLM, and over 27,000 of these horses occupy areas in Nevada. Thus, BLM's Nevada state office is responsible for the management of nearly 70 percent of all wild free-roaming horses in the United States (BLM 1988).

Since protection was initiated in 1971, horse populations have grown rapidly. Estimates of the rates of increase of individual populations range from 8-30%/year (National Research Council 1980, Wolfe 1980), but these authors suggested annual growth rates over 20% were unrealistic. Garrott (1990), however, examined fecundity and survival estimates available in the literature and BLM records of horse populations with pre- and post-capture counts and concluded that estimates of 20% annual growth were realistic. His study of 12 populations resulted in growth rates ranging from 15-27%/year, with an unweighted mean of 21%.

In passing the Public Rangelands Improvement Act of 1978 (PRIA) Congress expressed concern that the quality of western rangelands was being degraded and directed BLM to act on the problem. To control horse populations on western rangelands, BLM conducted periodic roundups to reduce horse numbers to an arbitrarily stated appropriate management level, then disposed of some of the "excess horses" through the Adopt-a-Horse program. This program has been controversial, with opposing viewpoints held by organizations interested in preservation of wild horses and by livestock interests, and has been expensive. BLM placed 9,500 horses through adoptions at a cost of \$3.5 million in FY 1985, but 10,000 horses were not adopted and were maintained in corrals at a cost of \$6 million (Boyles 1986).

Because the control of wild horse populations through roundups was deemed an unacceptable long-term solution to this management problem, the National Academy of Sciences Committee on Wild and Free-Roaming Horses and Burros recommended that the feasibility of using contraception be studied (National Research Council 1980, 1982). We began a project in September 1985 to develop chemical contraception in wild mares (Plotka et al. 1988a, 1988b, 1989, this report) and to test the efficacy of such a treatment in field conditions. In this paper we report the results of the field tests of wild mare contraception and discuss the management implications of these results.

Study Areas

Three BLM horse management units were selected in central and western Nevada for the study. The Wassuk Mountain unit is a 320 km² area near Hawthorne composed primarily of mountainous topography ranging from 1,275 m to 3,035 m in elevation. The Stone Cabin Valley unit is a 810 km² area 50 km east of Tonopah which consists of a broad relatively flat valley bordered by mountains on the east and west. Elevations in the valley range from 1,635 m to 2,150 m with the bordering mountains reaching 2,850 m. The Clan Alpine Mountain unit is a 1,310 km² area approximately 100 km east of Fallon. The area is primarily mountainous bordered by flat valleys to the east and west. The valleys range from 1,120 m to 1,670 m elevation with maximum elevation in the mountains of 2,860 m.

The 3 study areas are within the xeric Great Basin physiographic province which is characterized by hot summers and cool winters with most precipitation occurring as snow. Surface water is generally limited to scattered natural springs and wells. Vegetation communities within the 3 areas are segregated along elevational gradients. Valleys contain salt-desert scrub communities dominated by shad scale (*Atriplex* spp.), greasewood (*Sarcobatus* spp.), and winter fat (*Cercoides* spp.), and northern desert scrub communities dominated by big sagebrush

(*Artemisia artemisia*) and rabbitbrush (*Chrysothamnus* spp.). Mid-elevation mountainous slopes are dominated by pinyon pine (*Pinus monophylla*) and juniper (*Juniperus osteosperma*) woodlands with subalpine areas containing stands of limber pine (*P. flexilis*), whitebark pine (*P. albicaulus*), bristlecone pine (*P. aristata*), and spruce (*Picea* spp.). In 1987 BLM estimated 230, 475, and 1,450 horses in the Wassuk, Stone Cabin Valley, and Clan Alpine Mountain units, respectively. The areas were fenced to control livestock grazing, however, barriers were not sufficient to contain horse movements. Although horses in the Wassuk Mountain unit were isolated from other horse populations, both the Stone Cabin Valley and Clan Alpine Mountain units were bordered by numerous other horse management units.

Methods

Horses were captured January and August 1986 in the Wassuk Mountain and Stone Cabin Valley units, respectively. Horses in the Clan Alpine Mountain unit were captured August and September 1987. Animals were captured by using helicopters to locate and herd bands into portable corral traps erected at advantageous sites throughout each study area. Once captured, each animal was restrained in a padded squeeze chute, sexed and aged to the nearest year using incisor replacement and wear (Amer. Assoc. Equine Practitioners 1981). A blood sample was collected from the jugular vein of all horses in conjunction with studies of physical condition (Plotka et al. 1988a) and pregnancy rates (Garrott 1990). Mares that were estimated to be between 3 and 12 years old were selected for the study, however, 2-year old mares that were lactating at the time of capture were also used.

Studies using captive wild mares have tested a variety of implant construction techniques, natural and synthetic steroids, dosages, implantation sites, and surgical techniques (Plotka et al. 1988b, Plotka et al. this report). The 2 most effective treatments developed during these studies were 12 cc silastic rods impregnated with 8 g of ethinylestradiol alone (EE) or in combination with 36 g of progesterone (EE+PP) (Plotka et al. this report). Details on the construction of the silastic rods are described in Plotka et al. (this report). The EE treatments required 4 rods per mare while the EE+PP treatments required 10 rods per mare. Cost of the EE and EE+PP implants were \$90 and \$180 per mare, respectively. Placebo implants which consisted of 4 silastic rods containing no steroids were used as controls in the field experiments.

Forty mares from the Wassuk area were treated with placebo implants placed subcutaneously in the neck using procedures described by Plotka et al. (1988b). All treated mares in the Stone Cabin Valley and Clan Alpine Mountain study areas received implants intraperitoneally using procedures described by Plotka et al. (this report). In the Stone Cabin Valley 52 mares were

treated with EE implants and 49 with EE+PP implants. In the Clan Alpine Mountain area 49 mares were treated with placebo implants and 50 mares each were treated with EE and EE+PP implants.

All treated mares received an intramuscular injection of 10.5×10^6 IU benzethine penicillin (Flocillin, Bristol Laboratories, Syracuse, New York 13201). Each mare was fitted with an individually numbered 10-cm wide neck collar which contained a radio transmitter operating on a unique frequency. Each treated mare was photographed to record color and markings immediately after being processed which normally required < 5 minutes. All horses captured in a group were maintained in holding pens. Alfalfa hay and water were available for the animals held overnight. Following completion of treatments to all selected mares in each group, horses were released together.

Foaling status of experimental mares in each study area was assessed by conducting 4 aerial surveys spaced at approximately 2-week intervals between late April and early June 1988 and 1989. All flights were conducted using a Bell B-1 helicopter with a pilot and 1 observer. During each flight we systematically searched the study area to locate bands of horses. When bands were located, we recorded numbers of adults (≥ 1 yr) and foals in each. If collared horses were seen in the band, we noted which adults had foals trailing them and descended to read collar numbers and confirm foal assignments. Confirming information included observing a swollen udder on a mare or a mare altering her pace to stay next to a foal. Experimental mares not observed on the systematic flights were located using telemetry. If a foal was assigned to an experimental mare during any of the 4 spring flights, that mare was recorded as having foaled. Conversely, mares that were not assigned a foal during any of the flights were recorded as not having foaled that year. An additional flight was made each fall to monitor survival and examine fit and condition of collars. Collars were recovered from all dead horses discovered during the flights and an attempt made to determine if the mortality was natural or man-caused. Horses identified with ill-fitting collars were immobilized as described by Plotka et al. (1987) and collars were removed, replaced, or refitted.

For 2 weeks in May 1990 ground observations were made in the Stone Cabin Valley study area to assess contraception for a third year in that herd. Bands of horses containing experimental mares were located by searching the area on foot and in a vehicle and by using telemetry. These bands were then approached as closely as possible to positively identify experimental mares by tuning in the appropriate transmitter frequency, reading the number on the collar, and/or comparing a description of the mare in question to a photograph or written description. Once identities of mares were verified, we observed bands with binoculars or spotting scopes for 15-45 min to locate foals and assign them to

mares. This was usually determined by observing the foal suckling.

For each year the proportions of treated mares foaling and surviving in each study area were determined, and standard binomial 95% confidence intervals calculated (Zar 1974). Annual survival estimates were calculated as the proportion of instrumented mares available at the end of spring flights in year x that were alive at the end of spring flights in year x+1. Logistic regression models were used to assess affects of area, year, and implant treatments on foaling and survival rates (Fienberg 1980) using software Statistix (NH Analytical, St. Paul, MN 55108).

Results

A total of 992 horses were captured in the 3 study areas, and 291 mares were selected to receive hormone-treated or placebo implants (Table 1). Thirty-eight of the implanted mares were

Table 1. Number of wild horses captured in 3 BLM horse management areas in Nevada, number treated with silastic implants, and mortalities attributed to capture and handling of animals. Treatments included implants containing no hormones (placebo), 8 gm ethinylestradiol (EE), or 8 gm ethinylestradiol and 36 gm progesterone (EE+PP).

Area(Date)/ Treatment	No. Animals	Initial Capture	Mortalities			Prop. Mort.
			Darting	Other	Total	
Wassuk Mountains (Feb 1986)						
Placebo	41	0	0	0	0	0.00
Other	<u>21</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>0.00</u>
Sub-total	132	0	0	0	0	0.00
Stone Cabin, Valley (Aug 1986)						
EE	52	0	1	0	1	0.02
EE+PP	49	0	0	0	0	0.00
Other	<u>266</u>	<u>5</u>	<u>1</u>	<u>0</u>	<u>6</u>	<u>0.02</u>
Sub-total	367	5	2	0	7	0.02
Clan Alpine Mountains (Aug, Sep 1987)						
Placebo	49	1	0	17	18	0.37
EE	50	0	0	0	0	0.00
EE+PP	50	0	0	0	0	0.00
Other	<u>344</u>	<u>2</u>	<u>1</u>	<u>31</u>	<u>34</u>	<u>0.10</u>
Sub-total	493	3	1	48	52	0.11
Total	992	8	3	48	59	0.06

subsequently recaptured by helicopter darting to have their collars adjusted or removed. Eleven horses died due to capture and handling procedures; 6 deaths were associated with drugging, 2 resulted from trauma, and 3 were from unknown causes. An additional 48 horses, including 17 mares treated with placebo implants, were found dead 4-6 weeks after capture. These deaths were attributed to an unusual set of circumstances during the capture effort. An extensive review of the incident by the National Research Council committee overseeing the studies reviewed this incident but the report is not available. BLM also reviewed the incident and this report is a matter of public record. The deaths were not associated with the implant procedures.

Table 2. Foaling rates of mares receiving placebo implants and implants containing ethinylestradiol with (EE+PP) or without (EE) progesterone in 3 study areas in Nevada. F is the foaling rate, and CI is the 95% confidence interval of F.

Year Area/Treatment	No. of mares		F	CI
	Total	With foals		
1988				
Wassuk Mountains Control	33	15	.45	.28-.62
Stone Cabin Valley				
EE	45	5	.11	.02-.20
PP+EE	43	3	.07	.00-.15
Clan Alpine Mountains				
Control	31	13	.42	.25-.59
Both ^a	97	51	.53	.43-.63
1989				
Wassuk Mountains Control	30	21	.70	.53-.86
Stone Cabin Valley				
EE	35	1	.03	.00-.09
PP+EE	37	6	.16	.04-.28
Clan Alpine Mountains				
Control	31	14	.45	.27-.63
EE	45	4	.09	.01-.17
PP+EE	50	3	.06	.00-.12

^a Both treatments were combined because treatments were not scheduled to be effective until 1989.

Horses are postpartum breeders and have a gestation period of approximately 345-350 days (Ginther 1979). Therefore, mares foaling the spring following implanting would have been pregnant at the time they were captured and treated. Plotka et al. (this report) demonstrated that pregnant mares treated with the hormone implants carried the pregnancy to term. Hence, the first year we could expect to measure the impacts of the hormone implants on foaling rates was 1988 for the Stone Cabin Valley mares and 1989 for the Clan Alpine Mountain mares. The aerial flights in 1988 and 1989, therefore, provided data to assess the efficacy of the hormone implants for 2 years in the Stone Cabin Valley mares and 1 year in the Clan Alpine Mountain mares. Foaling rates for the placebo-treated mares in the Wassuk and Clan Alpine Mountain mares, as well as the Clan Alpine Mountain hormone-treated mares in 1988, ranged from 42-70%. In contrast, foaling rates of hormone-treated mares during the years contraception ranged from 3 to 16% (Table 2). Pooling the aerial counts by year indicated that about 10% of treated mares and 50% of control mares produced foals in 1988 and 1989. Neither area nor year had a significant effect on foaling ($P > 0.5$), but type of implant (treated versus control) was significant ($P < 0.001$). No difference in foaling rates could be detected between EE and EE+PP treated mares ($P = 0.18$) nor was there a significant difference in foaling rates of Stone Cabin Valley mares between the first (1988) and second (1989) year of implant efficacy ($P > 0.5$).

During ground observations in the Stone Cabin Valley study area during May 1990, we located and observed 45 treated mares. Foaling rates were 17% for EE treatments (4 of 24) and 14% for EE+PP-treated mares (3 of 21). Restrictions by BLM prohibited the collection of data on the other 2 study areas in 1990. As a result, no data are available that can serve as a control for the 1990 foaling rates of the treated Stone Cabin Valley mares. A comparison of the foaling rates of treated Stone Cabin Valley mares among years indicates that although the pooled foaling rate for treated mares in 1990 ($16 \pm 11\%$) was higher than the pooled rates for 1988 ($9 \pm 6\%$) and 1989 ($10 \pm 7\%$), the difference was not significant ($P > 0.5$).

Excluding the deaths 4-6 weeks after handling in the Clan Alpine, we discovered the deaths of 24 mares during the period January 1986 through July 1989 (Table 3). All carcasses examined were in a state of advanced decomposition, hence, causes of death were not determined. With the exception of 1 mutilated horse, all mortalities were assumed to be natural. The lowest annual survival rate documented, 89%, was for the Wassuk Mountain mares during 1986-1987. All other estimates of survival ranged between 93-100%. There was no difference in survival rates among areas, years, or treatments ($P > 0.5$).

Table 3. Interval survival rates of radio-collared wild mares treated with silastic implants containing no hormones (placebo) and implants containing hormones to block reproduction. Deaths resulting from capture or handling of horses are excluded from this table. Censored mares include those that lost transmitters or disappeared from the study area or those from which we removed collars.

Area/ Treatment	Interval		N	Deaths	Censor	Survival
	Begin	End				
Wassuk Mountains						
Placebo	1/86	7/86	41	3	0	0.93
	8/86	7/87	38	4	0	0.89
	8/87	7/88	34	1	0	0.97
	8/88	7/89	33	2	1	0.94
Stone Cabin Valley						
Hormone	8/86	7/87	101	2	0	0.98
	8/87	7/88	99	5	14	0.95
	8/88	7/89	80	2	6	0.98
Clan Alpine Mountains						
Placebo	10/87	7/88	31	0	0	1.00
	8/88	7/89	31	0	0	1.00
Hormone	9/87	10/87	100	0	0	1.00
	10/87	7/88	100	3	0	0.97
	8/88	7/89	97	2	2	0.98
Totals						
Placebo	8/86	7/87	38	4	0	0.89
	8/87	7/88	65	1	0	0.98
	8/88	7/89	64	2	1	0.97
Hormone	8/86	7/87	101	2	0	0.98
	8/87	7/88	199	8	14	0.96
	8/88	7/89	177	4	8	0.98

Discussion

Results of this study indicate that implants containing 8 g ethinylestradiol with or without 36 g progesterone were effective in reducing foaling rates in free-ranging wild mares for at least 2 reproductive seasons. There are no control data to compare the

third year foaling rates for treated mares from the Stone Cabin Valley study area. However, the low foaling rates suggest that the implants were probably effective for a third year, although their effectiveness may have been somewhat diminished. Plotka et al. (this report) tested the efficacy of both the EE and EE+PP implants on captive wild horses and found that both implants were 100% effective for 2 years with a small sample (n=8) of mares treated with the EE+PP implants failing to produce foals through a third year. Results from this study suggest that the hormone implants failed to block reproduction in approximately 10-16% of the treated mares. The differences in efficacy measured in the pen and field studies is believed to be due to the differences in the techniques for determining if a mare had foaled in a given reproductive season.

In the pen studies horses could be observed at close range throughout the foaling season, hence, the foaling status of the mares could be determined without error. However, the uncertainties of determining foal-dam pairs in bands of horses observed from a helicopter would suggest that some errors were likely in the field studies with barren mares occasionally assigned a foal and, conversely, foaling females classified as barren. Such errors would tend to overestimate foaling rates since a barren mare had 4 opportunities each year to be misassigned a foal and therefore classified as reproducing, while a reproducing mare had only to be assigned a foal once during the 4 flights to be correctly classified.

Another possible problem with determining the foaling status of mares in the field is the failure to detect a foal produced by a mare because the foal died before flights were initiated or was born and died during the 2-week interval between flights. Foal mortality appears to be highest during the first month of life (Welsh 1975, Boyd 1979, Keiper 1979, Berger 1986); therefore, such errors seem possible. Failure to detect all foals produced by experimental mares would tend to result in underestimates of foaling rates. Foal survival appears to be relatively high in most wild horse herds (Garrott 1990). Therefore, misassignment of foal-dam pairs was probably the more common error, suggesting the efficacy of hormone implants was underestimated.

Our data suggest that not only do hormone-containing implants successfully inhibit reproduction in wild horses, but the contraception is achieved without increasing mortality among treated horses. Annual survival of adults in long-lived species is generally high and most adult survival estimates for horses on western rangelands exceed 0.95 (National Research Council 1980, Wolfe 1980, Eberhardt et al. 1982, Berger 1986, Garrott 1990). Annual survival rates in this study were also high with the lowest survival estimate (0.89) occurring in a group of experimental horses which received placebo implants (Table 3). Survival rates in our treated herds were consistent with survival

noted in studies of other herds where horses received no treatments and often were not captured.

Plotka et al. (this report) failed to detect any conspicuous health problems in treated mares held in captivity nor among a small sample of treated mares sacrificed for post-mortem examination. However, failure to detect effects on health of mares may be due to the short term (3 years) of the study. Additional data would be useful to substantiate lack of detrimental effects on mares due to the hormone implants. Research aimed at determining hormone levels in muscle and organ tissue of treated mares and the resulting effects at higher levels of the food chain and the fate of implants in the peritoneal cavity would also be useful.

The data presented in this paper and that of Plotka et al. (this report) demonstrate that EE and EE+PP treatments of wild mares are highly effective contraceptives with minimum life spans of 3 years. Given the current restrictions on the disposal of wild horses removed from public lands and the apparent need to actively manage growing populations, manipulation of reproductive rates through the use of hormone implants may provide a viable tool to augment management of these controversial populations.

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Chapter 4

EFFICACY OF MALE-ORIENTED CONTRACEPTION IN FREE-RANGING WILD HORSES

By T. Eagle¹, S. Asa², R. Garrett¹, and D.B. Siniff¹

¹University of Minnesota, Minneapolis, Minnesota 55455

²St. Louis Zoo, St. Louis, Missouri 63110

Abstract

Twenty dominant band stallions were vasectomized in each of two areas (Flanigan in Nevada and Beatty Butte in Oregon) and radio transmitters in collars, and natural marking were used to follow these animals to monitor the effects of this treatment on band reproduction. Difficulty in maintaining contact with treated animals was encountered because the radio transmitters were often removed during male/male interactions. Results showed that for those bands where the treated stallions remained dominant, foaling rates were significantly reduced ($P > 0.05$) when compared to bands without vasectomized stallions. However, in one area (Flanigan) there was a seasonal effect, where the population foaling rates seemed to be reduced because of poor range conditions. During that year no difference between vasectomized and non-vasectomized bands were found. In general, it was considered that vasectomy of dominant stallions had the effect of lowering foaling rates as long as conditions for herd stability existed. The data indicated that the procedure was less effective if conditions encouraging turnover of dominant stallions existed. Further, the procedure was hypothesized to alter the overall seasonal synchrony of the foaling season.

Introduction

The use of sterilizing dominant stallions to reduce reproduction in wild equids has been studied in several locations. The rationale behind the research was that sterilizing the dominant stallion in polygynous species would effect fertility control by treating a minimum number of animals. Although the idea is a promising one, results of the research has been contradictory. McCort (1979) studied wild asses (*E. asinus*) in Georgia, and Nelson (1980) studied wild horses in New Mexico; both of these authors indicated that the sterilization of dominant stallions failed because band fidelity was weak or sub-dominant males in bands successfully bred mares. In contrast, hand, a study on a small number of animals in Montana and Idaho found a marked decrease in foal production between bands of horses in which the dominant stallions had been sterilized with a

microencapsulated testosterone compound and control bands (Kirkpatrick et al. 1982, Turner and Kirkpatrick 1982, Turner and Kirkpatrick 1986). In that study, treatment was effective for one breeding season. Because results of these studies conflicted, the Bureau of Land Management (BLM) requested additional research concerning the efficacy of sterilizing dominant stallions to reduce foal production in bands of wild horses. In this chapter we report the results of our study in one area in Nevada and one area in Oregon.

Study Areas and Methods

The two herd areas that were chosen for the vasectomy studies, were the Flanigan Herd Management Area (HMA) in northwest Nevada, and the Beatty Butte HMA in southeastern Oregon. The Flanigan area encompasses 66 km² and is primarily mountainous with maximum relief of approximately 1000 m. The Beatty Butte area encompassed 1769 km² and consisted mainly of broad flat plateaus with a maximum relief of approximately 500 m. Horse populations from both areas were managed by periodic removal of excess animals with the most recent removals prior to initiation of the study in September 1985 and November 1984 in the Flanigan and Beatty Butte areas, respectively. Aerial surveys conducted in the fall of 1985 counted 320 horses in the Flanigan area and 167 horses in the Beatty Butte area.

Horses were trapped for the study 5-10 December 1985 in the Flanigan area and 3-6 February 1986 in the Beatty Butte area. A helicopter was used to locate and herd individual bands into corral traps. Each horse in a band was funneled into a squeeze chute for inspection and handling. All horses in each band were sexed and aged based on incisor eruption and wear (Ensminger, 1969), and uniquely numbered collars were placed on all horses ≥ 3 years old. We photographed each collared horse to aid in identification during the study. After all horses from a band had been processed they were released as a group.

If more than one adult male was present in the band interactions between band members were observed until the dominant stallion could be identified. The dominant stallion in each group was vasectomized and identified with a numbered collar carrying a radio transmitter.

Dominant stallions were sedated with 3-5 mg etorphine hydrochloride mixed with 600-800 mg xylazine hydrochloride. Atropine sulfate (15 mg) was included to prevent the secondary atrioventricular block induced by xylazine. All three drugs were combined in the same syringe and injected into the jugular vein (Plotka et al., 1987). After a stallion was immobilized, the rear legs were secured with a rope, and the scroal area was washed with a Betadine solution. During the surgery, diazepam (20-40 mg) was administered intravenously to reduce muscular

rigidity and tremors (Plotka et al., 1987). A 2-3-cm incision was made along the midline of the scrotum and a loop of the vas deferens along with the artery and vein supplying blood to the testicle was pulled through the incision. The vas was separated from the blood vessels and a 1-2 cm segment was removed; both ends of the remaining vas deferens were then sutured closed. The procedure was then repeated for the other testicle. The incision was closed with 2-3 mattress sutures. Each animal received 10.5 x 10⁶ units of benzathine penicillin intramuscularly. Immobilization was reversed with diprenorphine and yohimbine as described by Plotka et al. (1987).

Attempts were made to observe each vasectomized stallion by conducting aerial surveys with a helicopter 3-4 times annually between April and August 1986-1988. We searched each study area systematically and recorded number of adults and foals in each band seen. When collared horses were seen, we flew close to the marked horses to read the number on the collar and recorded marked animals in each band. Early in the study, we tried to read each numbered collar; however, many marker collars became unreadable by 1987. Vasectomized stallions were identified by radio-frequency when numbers were illegible. If a vasectomized male was not observed on a survey an attempt was made to locate the horse using telemetry.

Data from aerial surveys were augmented by ground observations made by one of us (CSA) during behavioral studies which were conducted primarily in the Flanigan area during the spring and summers of 1987 and 1988. Observations were particularly valuable in collecting data on the presence of foals in bands where the vasectomized males had lost their collars and, therefore, could not be identified during aerial searches. These horses were positively identified using photographs taken when the animals were initially captured and collared.

The data collected consisted of a series of observations, via different methods at different points in time between spring 1986 to the late summer of 1988. Because the bands were often dynamic in their composition, we often had a slightly different structure each time a vasectomized stallion was observed. Thus, in the analysis data were summarized with a bias toward foal production. That is if a band was seen with a foal anytime during the summer observation period, it was considered that that band had produced a foal. Analysis consisted of summarizing the data into adult-foal ratios for the vasectomized bands and comparing these ratios via Chi-square criterion among years.

Collars on 11 vasectomized males were replaced during the study because of transmitter failures or damage to the collars apparently caused by horses biting and pulling on the material. These horses were immobilized using a drug-filled dart fired from the survey helicopter. The 7-cc darts contained a mixture of

approximately 5.5 mg of etorphine and 1.4 g xylazine (Plotka et al., 1987). The immobilization was reversed utilizing diprenorphine and yohimbine. Three males were captured from the Flanigan herd area in January 1986 and 8 males were captured from the Beatty Butte herd area in June 1987. Ten horses were successfully recollared but 1 male from the Flanigan herd area failed to recover from the tranquilizing drug.

Results and Discussion

We captured a total of 175 horses in the Flanigan area from 30 bands (Table 1). Twenty dominant stallions were vasectomized, radio collared, and released with their band. An additional 5 dominant stallions, which were not vasectomized, were radio collared and all horses in 5 bachelor bands were fitted with numbered marker collars. With the exception of a few bands occupying the north end of the study area, all horses were judged to be in very poor condition. One 17-year old stallion died while being handled, apparently due to a reaction with the drug. Another stallion in the band was vasectomized, as we assumed this stallion would become dominant.

Table 1. Age structure of wild horses captured in the Flanigan herd area in northwestern Nevada and the Beatty Butte area of southeastern Oregon. Numbers in parenthesis are the subset of males in each age category that were vasectomized.

Age	Flanigan herd			Beatty Butte herd		
	Total	Female	Male	Total	Female	Male
0	30	20	10	27	15	12
1	14	10	4	23	15	8
2	11	4	7	24	6	18(1)
3	22	11	11	2	1	1
4	16	10	6(1)	13	10	3
5	15	8	7(1)	12	6	6(1)
6	15	11	4(2)	6	5	1(1)
7	13	4	9(5)	14	8	6(5)
8	5	2	3(2)	9	7	2
9	0	0	0	0	0	0
10	1	0	1(1)	2	1	1(1)
11	9	6	3(3)	3	0	3(3)
12	3	1	2	0	0	0
13	1	1	0	0	0	0
14	3	3	0	1	0	1(1)
15	3	2	1	1	1	0
>15	14	5	9(6)	11	2	9(8)
Totals	175	98	77(21)	148	77	71(21)

In the Beatty Butte area, we captured a total of 148 horses and vasectomized 21 stallions (Table 1). One stallion that showed signs of radial nerve damage after surgery was euthanized when no improvement in his condition was noted after 3 days in captivity, hence, 20 vasectomized stallions were released. We collared horses from 19 distinct bands, including 2 bachelor groups and 2 harem groups from which the dominant stallion apparently escaped. During 1 drive the pilot deviated from the normal procedure of capturing individual bands, consolidating 32 animals for capture, representing 6 bands. We maintained the horses in the holding facility overnight anticipating the dominant stallions would isolate their bands from other horses. The following morning 6 groups of horses were apparent and we vasectomized apparent dominant stallions from 5 of the groups. No dominant stallion was identified in the final group.

The general age structure of horses captured on each area were quite similar (Table 1), with the dominant stallions tending to be in the older age classes. Subjectively, the animals in the Beatty Butte herd appeared in much better physical condition than those in the Flanigan HMA.

Tables 2 and 3 show the results from the overflights to monitor the effects of the vasectomies on foal production. As shown, we were able to classify bands into those with a vasectomized male and those without. In general, 3 flights were made in each area each spring, except in Beatty Butte in 1987 and Flanigan in 1988 where four flights were conducted. The April 10 survey in Flanigan was omitted from the analysis because it was prior to any significant foaling for that year.

Table 2. Summaries of wild horse observations obtained from helicopter survey conducted on the Flanigan herd area in northwestern Nevada between 1986-1988. Horses were marked with numbered collars with radio transmitters attached to the collars of all vasectomized (VX) males.

Year	Date	Total no. horses obs.	No. VX males iden.	No. marker horses iden.	Total no. bands* obs.	No. bands w/ VX male iden.	No. other bands
1986	6-8	376	9	59	56	9	47
	7-17	239	6	31	40	6	34
	8-13	184	7	28	37	7	30
1987	5-9	303	7	42	58	7	51
	6-3	264	3	29	34	3	31
	6-17	238	10	27	42	9	32
1988	4-21	261	6	17	53	6	47
	5-5	308	5	15	65	5	60
	5-19	305	5	11	57	5	52
	6-16	276	5	9	49	5	44

* A band was defined as 1 or more horses in close proximity

Table 3. Summaries of wild horse observations obtained from helicopter surveys conducted on the Beatty Butte herd area in southeastern Oregon between 1986-1988. Horses were marked with numbered collars with radio transmitters attached to the collars of all vasectomized (VX) males.

Year	Date	Total no. horses obs.	No. VX males iden.	No. marker horses iden.	Total no. bands* obs.	No. bands w/ VX male iden.	No. other bands
1986	6-14	237	16	53	36	15	21
	7-18	221	15	49	31	13	18
	8-14	212	15	39	35	13	22
1987	5-10	231	8	29	39	7	32
	6-4	227	8	27	40	8	31
	6-18	242	9	26	50	9	41
	7-17	250	10	26	48	6	42
1988	5-9	268	8	15	45	8	37
	5-20	245	8	14	46	8	38
	6-20	261	9	13	43	8	35

* A band was defined as 1 or more horses in close proximity

These data were first analyzed for year effects using the annual totals of bands with and without foals (Tables 4 and 5). It was felt these totals more closely represented the true yearly ratios between bands with and without vasectomized stallions, because individual flights were greatly influenced by weather conditions on the days of the censuses. Pooling across flights minimized this source of variance. Chi-square was used to test for change in ratios among the three years of foal to non-foal bands for bands without vasectomized males. The total number of bands with and without vasectomized males in these tables do not correspond to the numbers in Tables 2 and 3 because bands of 1 were included in summaries while in these tables (4 and 5) only bands of 2 or more are included.

This analysis showed a significant year effect for the Flanigan area but not the Beatty Butte area ($p > .05$). In the Flanigan, 1987 had very high foal production compared to 1986 and 1988. In general, foal production was much lower in the Flanigan than Beatty Butte which we attributed to overall range condition and thus condition of the horses.

Since Beatty Butte did not have a significant year effect, years were pooled when the treatment could have been effective (1987 and 1988) and the ratios of bands with and without foals were tested against the vasectomized and non-vasectomized

Table 4. Flanigan herd area in northwestern Nevada. Only bands of 2 or more horses are included in these data.

Year	Date	Bands w/ iden. VX male			Bands w/o iden. VX male		
		Total	No. w/foals	% w/foals	Total	No. w/foals	% w/foals
1986	6-8	9	7	78	46	22	48
	7-17	7	4	57	33	14	42
	8-13	6	4	67	29	11	38
1987	5-9	7	1	14	49	28	57
	6-1	3	1	33	30	19	63
	6-17	9	2	22	29	15	52
1988	4-21	6	1	17	44	10	28
	5-5	5	1	20	53	20	38
	5-19	5	1	20	51	22	43
	6-16	5	2	40	39	16	41

Table 5. Beatty Butte herd area in southeastern Oregon. Only bands of 2 or more horses are included in these data.

Year	Date	Bands w/ iden. VX male			Bands w/o iden. VX male		
		Total	No. w/foals	% w/foals	Total	No. w/foals	% w/foals
1986	6-14	15	11	73	17	6	35
	7-18	11	9	82	16	10	63
	8-14	13	10	77	19	11	58
1987	5-10	7	4	57	26	11	42
	6-4	9	5	56	28	15	54
	6-18	8	1	13	37	22	59
	7-17	4	2	50	38	24	63
1988	5-9	8	1	13	34	15	44
	5-20	8	2	25	37	17	46
	6-20	7	4	57	33	23	70

categories. We found a significant difference ($p>0.05$) between bands with vasectomized males and those without, indicating significant decline in foal production for bands where the

Table 6. Foaling status of wild horse bands containing vasectomized stallions in the Flanigan herd area of northwestern Nevada. Band size was calculated as the mean of all observations and a band was considered to have a foal if a foal was observed at least once. Observations included 3-4 aerial surveys conducted annually during the spring-summer period supplemented with ground observations during the spring and summers of 1987 and 1988.

Vasectomized stallion	1986			1987			1988		
	No. Obs.	Band Size	Foal Status	No. Obs.	Band Size	Foal Status	No. Obs.	Band Size	Foal Status
201	2	10	Foal	3	6	None	2	6	None
202	2	2	None	7	3	None	2	3	None
204	1	61	Foal	2	4	None	4	9	Foal
205				9	9	Foal			
206							8	4	None
207	2	6	None						
209	2	15	Foal	1	26	Foal			
210									
211	3	6	Foal	19	5	None	11	6	Foal
212	1	5	None	3	4	None	1	5	None
213				1	4	None	1	5	None
214				6	6	Foal	10	3	None
215				20	8	None	7	7	None
216	2	6	Foal	3	10	Foal	3	17	None
217							1	9	Foal
218							4	8	Foal
219	3	9	Foal	10	9	None			
220				6	8	Foal			
224	1	4	Foal	4	6	None	4	6	None
239									
523				2	3	None	2	5	None
529				3	10	Foal	4	6	None

dominant stallion was vasectomized. For Flanigan the situation was complicated because of year effect and thus each year was tested separately. For 1987, when foal production was high in the Flanigan, the bands with vasectomized males showed a significant decrease in foal production ($P > 0.05$; Chi sq. = 9.41; 2 d.f.) but this was not true in 1988 ($P > 0.10$, Chi sq = 3.2; 2 d.f.) when overall foal production was low. In this latter case there was some decrease in foal production in the vasectomized bands, but we feel poor overall foal production tended to contribute so that the difference between treatment and controls was not sufficient to show statistical significance at the 5% level.

Overall it appears some reduction in foaling does occur when dominant stallions of a band are vasectomized. The ability of the treated stallions to maintain dominance and prevent other males from breeding mares in their band no doubt depends on many factors such as age of the stallion, general range conditions and population size (is the herd near carrying capacity so conditions are crowded). Some insight into these considerations can be gained by examining the detailed status of individual stallions as shown in Tables 6 and 7. These tables trace what each treated stallion did throughout our observation period. The information on band size and foal status is our best summary of the status for a given stallion for any given year. Here it is possible to test foal adult ratios by year, using 1986 as the control. The band sizes were summed to obtain the number of adults. We did not test the Flanigan because of the significant year effect previously discussed. In this case a significant shift toward few foals was found when comparing 1987 and 1988, where the vasectomized stallions were effective, with 1986 where they were not ($P > 0.05$, Chi sq = 7.0, 2 d.f.). These results are consistent with the previous findings where bands with and without foals was the criterion for comparison.

The general effect of vasectomizing dominant stallions seems to be the lowering of foal production. There are potential side effects which need to be considered. Horses are polyestrus, thus if the mares do not conceive during the post-partum estrus they will cycle again in 21 days. If this continues, there is a possibility that a shift in the time of foaling could occur since gestation is about 1 year. Chapter 5 of this report explores the consequences of this phenomena.

Table 7. Foaling status of wild horse bands containing vasectomized stallions in the Beatty Butte herd area of southeastern Oregon. Band size was calculated as the mean of all observations and a band was considered to have a foal if a foal was observed at least once. Observations included 3-4 aerial surveys conducted annually during the spring-summer period supplemented with ground observations during the spring and summer of 1987.

Vasectomized stallion	1986			1987			1988		
	No. Obs.	Band Size	Foal Status	No. Obs.	Band Size	Foal Status	No. Obs.	Band Size	Foal Status
519	1	2	None						
520	3	8	Foal	2	8	Foal			
521	3	5	Foal						
532	1	6	None						
537	3	6	Foal	4	11	None	3	5	None
696	3	6	Foal	5	5	Foal	3	6	Foal
697	2	4	None	1	1	None	1	1	None
701	2	5	Foal	4	10	Foal	3	12	Foal
718	1	10	Foal						
719	3	6	Foal	2	12	None	1	3	None
732	3	4	Foal	5	4	Foal	3	3	None
733									
734	3	10	Foal	3	13	None	3	7	Foal
735	3	12	Foal						
738	3	8	Foal	3	4	None			
739	3	6	Foal	2	14	Foal	3	8	Foal
741									
744	3	11	Foal	4	6	Foal	1	6	None
747	3	15	Foal	5	9	Foal	1	6	Foal
750	3	8	Foal	4	4	None	3	4	None

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Chapter 5

LIMITATIONS AND CONSEQUENCES OF MALE-ORIENTED CONTRACEPTION FOR CONTROLLING WILD HORSE POPULATIONS

R.A. GARROTT and D.B. SINIFF
University of Minnesota, Minneapolis, MN 55455

Abstract

A computer program was developed which mimicked key features of wild horse (*Equus caballus*) population dynamics and breeding cycles. A series of simulations were performed to explore the potential of male-oriented contraception techniques to inhibit reproduction and the possible changes such techniques may cause in the reproductive cycle. The results indicate that the normal seasonal foaling pattern of wild horses would be disrupted by introducing significant numbers of infertile males into the population. As the probability of mating with an infertile male increased, fewer mares conceived during their first estrus cycle and increasingly higher numbers of mares did not mate with a fertile male until cycling several times (Fig. 4). Since each estrus cycle requires approximately 21 days to complete, every time a mare came into estrus and failed to mate with a fertile male her potential conception date was delayed by 3 weeks and, hence, her foal would be born 3 weeks later in the following summer. The consequences of such conditions would undoubtedly be higher mortality of foals during the winter. Although this would have the affect of increasing the effectiveness of the contraceptive technique to reduce population growth, one would have to question the humaneness of the process. Simulation results also indicated that the probability of mating with a fertile male had to be reduced to at least 0.2 to have an appreciable affect on population growth rates. These results suggest that sterilizing a large proportion of the dominant stallions in a population may have only limited impacts on annual growth rates if subordinate males and/or males without harems perform as little as 10-20% of the breeding. The potential disruption of the seasonal reproductive cycle and the apparently limited efficacy of male-oriented contraception to reduce reproduction would appear to limit the utility of such techniques as management tools for controlling wild horse populations.

Introduction

During the last 15 years there has been considerable interest in controlling wild horse populations in the western

United States by inhibiting reproduction through the use of contraceptive devices. From the outset of wild horse contraceptive research in the mid-1970s, there has been considerable controversy about whether male or female oriented contraceptive tools hold the most promise for practical population management. Turner and Kirkpatrick (1986a) provided one view, arguing that male-oriented contraceptive techniques provided several advantages over the currently available technology for female-oriented contraception. A committee of scientists representing the National Research Council (1982), however, concluded that research into female-oriented contraception was preferable. Research aimed at developing effective contraceptive tools has been conducted on both males and females. The results of 2 male contraceptive studies have been reported. The first was a study of injectable solutions of testosterone cypionate and testosterone propionate (Turner and Kirkpatrick 1982, 1986a) and the second was the vasectomy study reported in this document (Eagle et al. this report). In both studies, dominant harem stallions were treated and the results suggested that these techniques may have resulted in a decrease in foal production, indicating that male-oriented contraceptive may hold promise as a management tool.

In reviewing the available literature on wild horse reproduction, physiology, and social structure we became concerned that the application of male-oriented contraception may result in some undesirable changes in the normally seasonal reproductive patterns observed in wild horse populations. Horses have a 340-350 day gestation period and undergo a post-foaling heat approximately 5-15 days after parturition (Ginther 1979). These characteristics essentially lock mares into a relatively fixed yearly reproductive cycle which dictates that if a mare conceives during the post-foal heat she will produce consecutive foals at essentially the same time each year. If the mare fails to conceive during the post-foal heat she will cycle at approximately 21-day intervals (Ginther 1979). Although there are many observations of wild horse breeding activity throughout the year (Welsh 1975, Nelson 1978, Berger 1986), studies of reproductive hormones indicate that ovarian cycles are normally seasonal, beginning in April and extending through September or October (Turner and Kirkpatrick 1986b, Plotka et al. 1989). Although mares may cycle for 5-7 months each year, most foaling occurs during a relatively brief period from late April to June (Feist and McCullough 1975, Boyd 1979, Keiper 1979, Berger 1986, Kirkpatrick and Turner 1986), suggesting that most mares are bred during this period.

If a portion of the dominant males in a population are rendered infertile by some contraceptive technique then mares that are bred by these males will not conceive, hence, they will cycle and become receptive again. If only the infertile male continues to breed the mare, she will continue cycling until late

summer or fall when ovarian activity ceases. Under these circumstances the contraceptive technique has been successful as, the mare fails to produce a foal during the following year. There have been a number of studies, however, that indicate that not all mares in a harem are bred by the dominant stallion and there is enough exchange of animals among bands that mares have opportunities to breed with other males (Miller 1979, Nelson 1978, Bowling and Touchberry 1990). If the mare cycles 6-10 times in a year there are enough opportunities to breed that even if the probability of mating with a fertile male is small she may have a relatively high chance of conceiving. The more times a mare cycles the further from the spring breeding season she drifts, hence, the later the foal will be born if she is successfully bred. Once out of the normal seasonal breeding and foaling cycle, the yearly cycle of gestation and post-foal heats could make it difficult for the mare to regain seasonal synchrony. If a large proportion of the female population were affected in this manner it could result in the complete disruption of the normal seasonal reproductive pattern of the population.

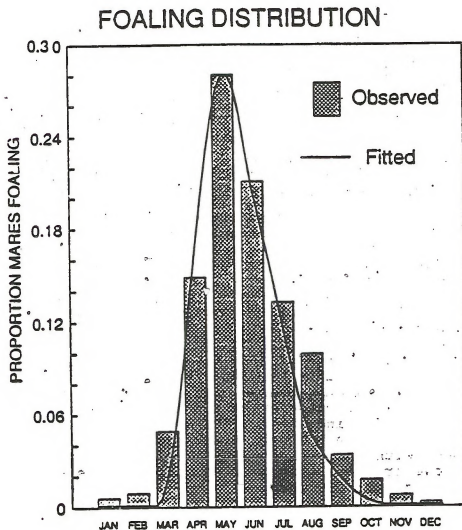
The goals of this study were to determine the normal seasonal reproductive pattern of wild horses in the western United States and construct a probability distribution which mimics this pattern. This distribution was used in conjunction with population models presented by Garrott (1990) to develop a computer program that imitates the key processes of the wild horse reproductive cycle. Simulations were performed using the program to explore the potential of male-oriented contraception to inhibit reproduction and the possible changes such programs may cause in the normal seasonal reproductive cycle

The Foaling Season

Information on the normal foaling season of wild horses was obtained from records of horses removed from Bureau of Land Management (BLM) lands in Nevada between 1979 and 1987. Of the 33,521 horses captured during this time, 5993 animals were judged to be foals. The age of 4678 of the foals was estimated to the nearest month based on the eruption patterns of incisors (Amer. Assoc. Equine Practitioners 1981). The month these foals were born was then estimated by back dating to develop a histogram of the seasonal foaling pattern. The resulting histogram (Fig. 1) indicates that the foaling season extends from March through September with the peak in May. Foaling may occur throughout the year; however, less than 3% of the foals were born between October and February (Fig. 1). The criteria used to estimate the ages of foals were not precise and aging errors undoubtedly occurred; therefore, the histogram derived from these data must be considered an approximation of the true foaling distribution. The general distribution in Fig. 1, however, is in close agreement with the observations of other investigators who have

Figure 1.

The proportion of mares foaling throughout the year and the frequency distribution fitted to the data. The data were derived from 4678 foals removed from federal lands in Nevada between 1979 and 1987. The age of foals was estimated to the nearest month using incisor eruption patterns and the date of birth was determined by back dating.



studied reproduction in wild horse herds (Feist and McCullough 1975, Boyd 1979, Keiper 1979, Berger 1986, Kirkpatrick and Turner 1986). We, therefore, assume it provides an adequate representation of the seasonal foaling pattern for the purposes of this study. Since mares enter estrous soon after foaling we also assume these data represent the normal seasonal breeding pattern as well.

To simulate the normal seasonal variation in reproduction in the computer program we wanted to be able to randomly assign each mare in the program a foaling date. This required developing a frequency distribution which adequately mimicked the data presented in Fig. 1. We chose to use a cosine curve for this purpose. However, the right side of the curve was modified by trial and error until an appropriately skewed distribution was created which emulated the asymmetry evident in Fig. 1. For the purposes of the computer simulations the small amount of reproduction that occurs between November and February was ignored.

Development of the Simulation Program

The computer program developed for the simulations was composed of two principle components, a population model and an annual breeding cycle model for individual mares. The population model was constructed for only females and utilized age-specific fecundity and survival schedules to project an initial population forward in time. The basic model consisted of the number of mares in each of 26 age classes ranging from 0 (foal) to 25 years old. Thus, the model required 3 user-specified vectors, the structure of the initial population, defined by the number of females in each age class, an age-specific fecundity schedule, and an age-specific survival schedule. Garrott (1990) presented a series of survivorship and fecundity schedules which were formulated using the models presented by Eberhardt (1985). We chose to use the F2 fecundity schedule which was derived from reproductive data compiled for 1144 mares captured immediately after the foaling season in Nevada (Garrott 1990). The S1 survivorship schedule was used as it represents the only age-specific survival data available for a wild horse population. This schedule was developed from 11 years of data collected on animals in the Pryor Mountain herd in Montana (Garrott 1990). The survivorship schedule was converted according to Caughley (1977) to obtain the annual age-specific survival rates required for the population model.

The stable age distribution for these 2 schedules was determined by projecting an arbitrary initial population forward 10 years using a Leslie matrix type model (Leslie 1945). The age structure of the projected population in year 10 was then used to calculate the number of mares in each age class for an initial

population of 1000 animals. No density-dependent mechanisms were incorporated into the model, creating a population growing geometrically at a rate of approximately 21% annually. Data presented by Garrott (1990) indicated that most wild horse herds throughout the West have grown at annual rates of 15-27%, thus the demographic characteristics of the population model are similar to what might be considered typical of wild horse populations.

We chose to only model the female segment of the population since we are concerned primarily with seasonal foaling patterns and population growth which are both determined by the female component of the population. The male component of the population was represented in the program by a single parameter which defined the probability of mating with a sterile male. By using this approach to the male component of the population we assume that all mares in the population have the same probability of mating with an infertile male. In reality, reproductive age females are usually associated with a harem group which is controlled by a single mature stallion (Feist and McCullough 1975, Miller 1979, Berger 1986). If the stallion has been rendered infertile by some contraceptive technique than mares in his harem have a relatively high probability of mating with this infertile male regardless of the proportion of infertile males in the population as a whole. Not all females, however, are bred by the dominant male in their harem and females may temporarily or permanently leave the harem group and associate with other horses (Miller 1979, Nelson 1979, Bowling and Touchberry 1990). It would have been extremely difficult to attempt to mimic the complex social and behavioral interactions that determine which male mates with each receptive female in a population because our understanding of this dynamic process is relatively poor. Therefore, we chose to use a simple probability value for determining if a female mates with an infertile male.

The breeding cycle component of the program traced individual mares through the annual reproductive cycle. When the initial population was read into the program each mare was randomly assigned a foaling date using the frequency distribution fitted to the Nevada foaling data. At the start of the annual loop a random number was drawn to determine if the mare survived to the beginning of the breeding season. If she survived her age was incremented by 1 year and a second random number was drawn to determine if the mare would attempt to breed. The survival and breeding determinations were made based on the mare's age and the age-specific survival and fecundity schedules.

For mares which attempted to breed, a random number was drawn to determine if the mare bred with a sterile or fertile male. If she mated with a sterile male the foaling date was incremented by 21 days (the normal estrus cycle) and another random number was drawn to determine if her second mate was

sterile or fertile. This sequence continued until the mare was bred by a fertile male or cycled beyond October, at which time she was assumed to cease cycling and remain barren. If the mare was successfully bred she was assumed to foal one year later. A random number was drawn to determine the sex of each foal produced and all female foals were added to the mare population. A new foaling date was drawn from the normal foaling distribution for all mares which remained barren for a year. This feature of the program allowed any mare which had her annual reproductive cycle shifted to the summer-fall period due to repeated mating with infertile males to reestablish a normal seasonal reproductive pattern.

Each simulation was conducted for 10 years with output consisting of tabulation of the population and reproductive statistics of interest for each year of the simulation. Demographic output included the number of mares in the population at the beginning of the year, the number of mares that died, the number of foals born, and the number of mares in the population at the end of the year. The growth rate of the population was determined using log-linear regression techniques (Eberhardt, 1987). Reproductive output included the number of foals born in each month, the number of estrus cycles required for each mare to conceive, and the number of mares which failed to conceive because all matings were with infertile males. Eight probabilities of mating with a sterile male were simulated, 0.00, 0.50, 0.60, 0.70, 0.80, 0.90, 0.95, and 0.98. Since the model was stochastic each simulation resulted in different results; however, differences were slight so we have presented the results from a single simulation for each of the mating probabilities.

Effects of Sterile Males on the Foaling Season

The simulations indicated that the normal seasonal foaling pattern of wild horses would be disrupted by introducing significant numbers of infertile males into the population (Fig. 2). The affect of infertile males can be characterized as a change from a highly seasonal foaling distribution, peaking in May, to a less synchronous foaling season spread more evenly over the entire spring through fall period. The distributions presented in Figure 2 illustrate that this disruption was not a gradual process, but occurred during the first foaling season after introduction of the infertile males. Once the shift in the foaling distribution occurred it remained relatively unchanged throughout the 10-year simulation (Fig. 2). The magnitude of the change was related to the proportion of infertile males (Fig. 3). As the probability of mating with an infertile male increased, the foaling distribution became increasingly flattened and shifted increasingly further toward late summer and fall months (Fig. 3).

Figure 2.

Temporal changes in the seasonal foaling pattern of a simulated population of mares breeding with increasingly higher proportions of sterile males. Closed squares represent the normal foaling distribution at year 0, crosses are year 2, diamonds are year 5, and triangles are year 10.

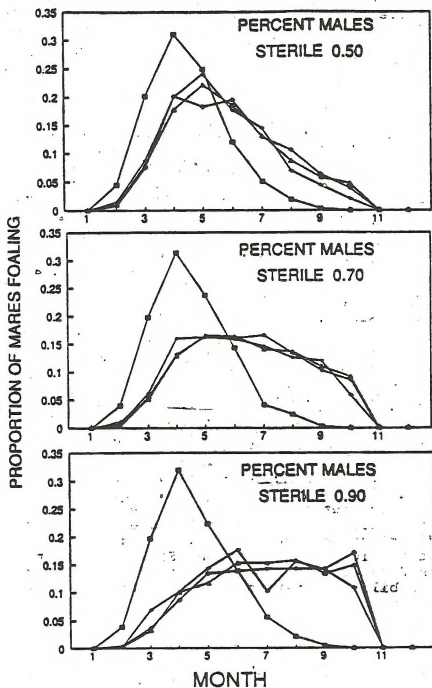
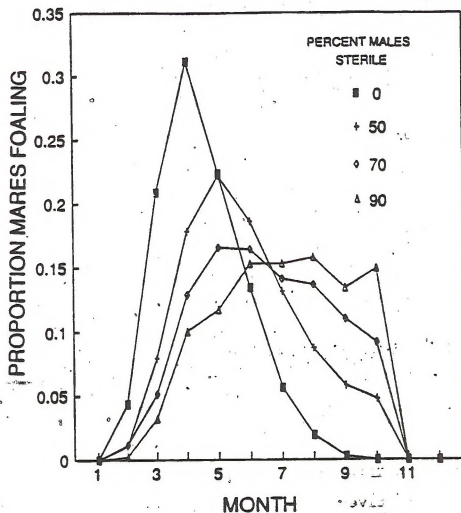


Figure 3.

Changes in the normal seasonal foaling pattern of a simulated population of wild horses where increasingly higher proportions of the males are rendered infertile through a contraceptive treatment. The distributions represent the foaling pattern from the tenth year of each simulation.



The reason for the changes if the foaling season can be understood by examining the number of times mares cycled before mating with a fertile male (Fig. 4). The program was structured so that all mares conceived during their first estrus cycle (the post-foal heat) if no infertile males were present in the population. As the probability of mating with an infertile male increased, fewer mares conceived during their first estrus cycle and increasingly higher numbers of mares did not mate with a fertile male until cycling several times (Fig. 4). When the probability of mating with an infertile male was between 50 and 70% at least half the mares conceived by the second estrus cycle and a minimum of 75% conceived by their fourth cycle. When the probability of mating with an infertile male became relatively high (80-90%), however, a maximum of 35% of the mares conceived by the second cycle with no more than 60% conceiving by the fourth estrus cycle (Fig. 4). Since each estrus cycle requires approximately 21 days to complete, every time a mare came into estrus and failed to mate with a fertile male her potential conception date was delayed by 3 weeks and, hence, her foal would be born 3 weeks later in the following summer.

Although we used a computer program to simulate the cycling of mares and their probability of conceiving, the same results can be obtained by simply multiplying out the probabilities. Let S represent the probability of mating with a sterile male and F represent the probability of mating with a fertile male, which is 1-S. Then the probability a mare will mate with a fertile male during her first estrus cycle is simply F. The probability of mating with a fertile male during the second cycle would be $S \cdot F$, or the probability of mating with a sterile male during the first cycle times the probability of mating with a fertile male during the second cycle. This simple equation can be generalized for determining the probability of a mare mating with a fertile male during any estrus cycle:

$$P_i = S^{i-1} (1-S)$$

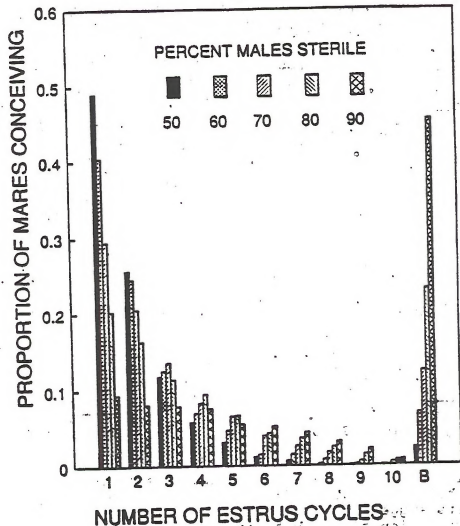
where P_i is the probability of mating with a fertile male on the i th estrus cycle. For example, if the probability of mating with a sterile male (S) is 0.8, then the probability a mare will mate with a fertile male for the first time on her sixth estrus cycle (P_6) is $0.8^5 \cdot 0.2$ or 0.066.

Effects of Sterile Males on Population Growth

The effectiveness of a male-oriented contraceptive program depends on each female mating with an infertile male during all periods of receptivity throughout the March through October interval when cycling. Since a female may cycle 6-10 times during this interval she has many chances of coming into contact with a fertile male and conceiving, which implies that the probability of mating with a sterile male must be quite high in order to assure that a female remains barren. This relationship

Figure 4.

The proportion of mares in a simulated population conceiving on their first through tenth estrus cycles when increasingly higher proportions of males were rendered infertile through a contraceptive treatment. The B histogram represents the proportion of mares that cycled throughout the spring and summer but never mated with a fertile male and, hence, remained barren. Data are from the tenth year of each simulation.



is readily evident in the histogram labeled B in Figure 4. When probabilities of mating with a sterile male are within the 0.5-0.7 range less than 15% of the mares fail to conceive. Even when the probability of mating with a sterile male is 0.9, less than 50% of the mares failed to conceive.

The implications of this relationship with respect to the potential effectiveness of male-oriented contraception to reduce population growth rates is illustrated in Figure 5. Treatments that reduce the probability of mating with a fertile male to as low as 0.3 had little impact on population growth, with the annual growth rate decreased from 21% for the untreated population to only 19% for this relatively high level of treatment. Only when the treatment level was high enough to reduce the probability of mating with a sterile male to 0.8 or higher did there begin to be an appreciable effect on population growth, with the depression of growth rates becoming increasingly sensitive to small changes in treatment level as the probability of mating with a sterile male approaches 1 (Fig. 6).

The reduction in growth rates demonstrated from these simulations was the result of a decrease in reproduction. In reality, there may also be a reduction in foal survival which would further decrease population growth. If we assume that producing foals in the spring has an adaptive advantage and, hence, selected for, then foals produced outside the normal spring foaling season should have a lower survival rate than foals born during the foaling season. We have shown previously that as the probability of mating with a sterile male increases a higher proportion of the foals are born later in the summer or fall when they would have little chance to grow before the onset of winter. In the initial simulation program foal survival was held constant regardless of when the foal was born.

To explore the potential affects on growth rates if survival of late-born foals decreased we modified the program and ran another set of simulations. In the modified program we decreased foal survival 0.01/day for foals born after July 30. This linear function dropped the mean survival from 0.94 for foals born prior to August to 0.79, 0.49, and 0.29 for foals born during the months of August, September, and October, respectively. The affect of this modification in the program was to lower annual population growth rates by an additional 1-3%, depending on the probability of mating with a sterile male (Fig. 6). These results suggest that the effectiveness of male-oriented contraception to inhibit population growth may be enhanced by the disruption of the normal seasonal foaling pattern.

Conclusions

The concept of male-oriented contraception appears to be attractive because there is a perception that sterilizing

Figure 5. Ten year trends in a simulated population of 1000 mares where increasingly higher proportions of males were rendered infertile through a contraceptive treatment.

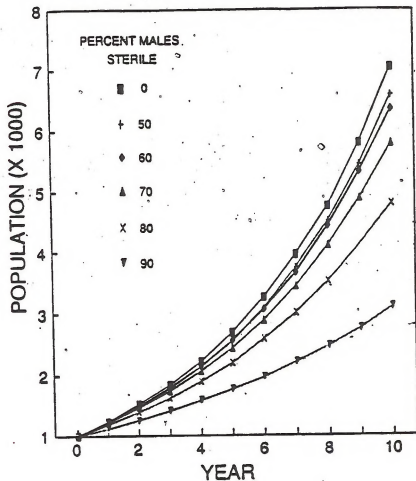
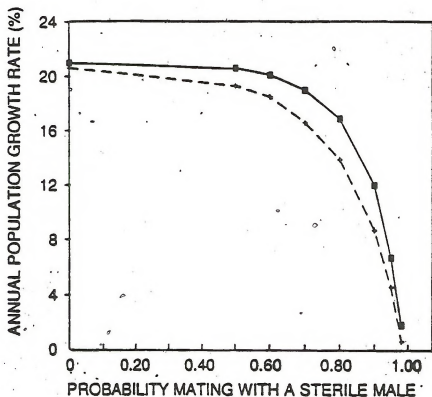


Figure 6. Changes in the annual growth rate of a simulated population of mares subjected to increasingly higher probabilities of mating with infertile males. The solid line represents growth rates where foal survival remains constant regardless of the time of birth. The dashed line represents growth rates when foal survival was decreased 0.01/day for animals born after July 30.



dominant stallions, which represent a small proportion of any population, will result in inhibiting reproduction in a large proportion of the mares in the population. Such a concept seems to be more practical and economical than female-oriented contraception where a larger proportion of the population must be treated. Some special interests groups concerned with animal welfare also appear to favor male-oriented contraception because they feel the techniques may be less intrusive and require treating fewer animals, therefore, are more humane than female-oriented contraception.

The research of Turner and Kirkpatrick (1982, 1986a) and Eagle et al. (this report) demonstrate that male contraceptive techniques can reduce foaling rates. However, results of the simulation exercises reported here suggests that a large proportion of the males in a population will need to be treated if significant reductions in population growth are required. Sterilizing all the dominant stallions in a population may not be an adequate treatment if subordinate males and/or males without harems perform as little as 10-20% of the breeding as suggested by numerous studies (Miller 1979, Nelson 1979, Bowling and Touchberry 1990). Although the simulations suggest that the efficacy of male-oriented contraception may be somewhat limited the most serious obstacle to its application as a population management tool is the potential disruption of the seasonal foaling pattern. Seasonal reproduction has evolved in most temperate animals presumably as a response to the predictable pattern of food abundance and scarcity caused by seasonal climatic changes. Shifting the foaling season toward the summer or fall months would result in large numbers of relatively young foals entering the winter without adequate forage for themselves and the lactating dams or adequate body reserves to endure long periods of nutritional stress. The consequences of such conditions would undoubtedly be higher mortality of foals during the winter. Although this would have the effect of increasing the success of the contraceptive technique to reduce population growth, one would have to question the humaneness of the process.

The simulation program used to obtain the results presented in this paper had many limitations and was extremely generalized. Its major weakness was a lack of any behavioral or social mechanisms which certainly influence mating and reproduction in the real world. Despite these limitations we think the general conclusions that can be drawn from this exercise are valid and, in many ways, relatively intuitive when one considers some of the fundamental aspects of wild horse reproduction. These results may also apply to other polyestrous large mammals which restrict their reproduction to specific seasons.

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Chapter. 6

A COMPARISON OF MANAGEMENT ALTERNATIVES FOR LIMITING WILD HORSE POPULATIONS

R.A. GARROTT, D.B. SINIFF, J.R. TESTER, and T.C. EAGLE
University of Minnesota, Minneapolis, MN 55455

and

E.D. PLOTKA

Marshfield Medical Foundation, Marshfield, WI 54449

Abstract

A wild horse (*Equus caballus*) population model was constructed to explore the potential application of mare contraceptive devices as a management tool and contrast its use, both demographically and economically, with the current management program. Three management alternatives were simulated, 1) non-selective removals, 2) mare contraception, and 3) selective removals in conjunction with mare contraception. All three alternatives could effectively control growth rates of wild horse populations. However, the characteristics of each management program were quite divergent with costs and the number of animals manipulated the major differences among the management alternatives. In general, the non-selective removal program required capturing and handling the fewest animals while the mare contraception program required handling nearly twice the number of horses. Costs associated with the non-selective removal program, however, were at least double the costs of the mare contraception program, primarily due to the high costs of disposing of captured horses. The program using selective removals in conjunction with mare contraception was intermediate in both number of horses manipulated and cost between the other two management alternatives. We conclude that mare-oriented contraception appears to be a viable tool for managing wild horse populations in the western United States. Incorporating contraceptive techniques into the current management program could minimize population fluctuations and significantly reduce costs. Although contraceptive programs would require capturing more animals than the current management program, this trade-off does not appear to be overtly detrimental because capturing horses is relatively easy and inexpensive and certainly limits the number of animals that are determined for long-term captivity.

Introduction

Wild horse populations in the western United States have been protected by federal law since 1971, with the Bureau of Land

Management (BLM) the primary federal agency responsible for population management. This program has been embroiled in controversy since its inception. Primary points of contention have been the humane treatment of animals, the number of horses to be maintained on federal lands, and the techniques used to reduce populations which are deemed excessive. Currently populations are reduced by using helicopters to periodically capture large numbers of horses from specific areas. This program has resulted in the removal of over 100,000 animals from federal lands since the mid-1970s (unpubl. data, Bureau of Land Management).

Disposal of captured horses has been a major problem with the removal program. In response to pressure from horse protection organizations the BLM has imposed a moratorium on the destruction of healthy animals. Horses are disposed of through the Adopt-A-Horse program, which transfers animals to private ownership. The number of horses removed from federal lands, however, has often exceeded public adoption demand, resulting in the maintenance of up to 10,000 unwanted animals in feedlots during years of aggressive removal programs. The humaneness of the feedlot program as well as its costs (>\$6 million/year, in 1986 and 1987) have stimulated considerable debate.

One possible alternative is the use of contraceptive devices to reduce reproduction. Initial attempts to develop a contraceptive device for wild horses focused on the temporary sterilization of harem stallions. A committee of scientists representing the National Research Council, however, concluded that female oriented contraceptive techniques would have a higher probability of success when applied on a management scale (National Research Council 1982). The recommendations of the National Research Council committee resulted in a 4-year research grant (1985-89) with the primary goal of developing a contraceptive device for mares (National Research Council 1982). This research has led to the successful development of a hormone containing Silastic implant which is capable of blocking conception in mares for at least 3 years (Plotka et al. this report, Eagle et al. this report). Controlled experiments have demonstrated the efficacy of the contraceptive device on relatively large numbers of captive and free-ranging individuals, however, its utility for managing free-ranging populations has yet to be addressed. This paper describes the results of population simulations exploring the potential application of the mare contraceptive device as a management tool and contrasts its use, both demographically and economically, with the current management program.

The Population Model

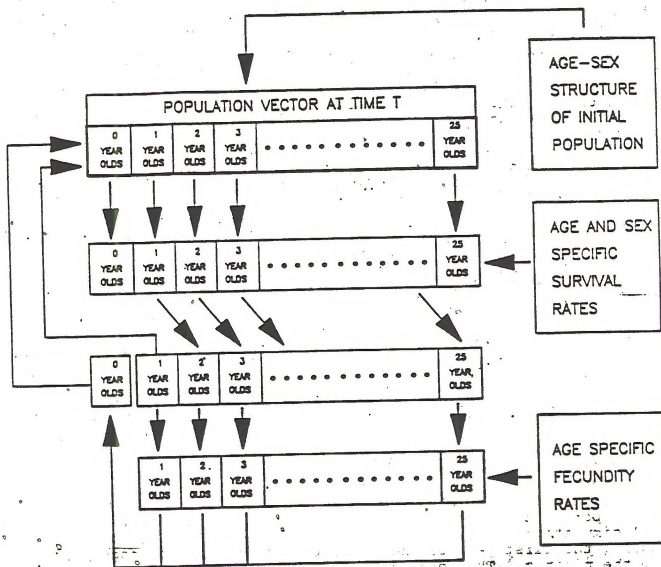
A deterministic, age-structured population model was constructed using a commercial spreadsheet program. The basic

population model consisted of the number of males and females in each of 26 age classes ranging from 0 (foal) to 25 years old. General mechanics of the model are similar to that of a Leslie matrix and are illustrated in Figure 1. Briefly, the number of horses in each age class at time t was multiplied by age-specific survival rates and incremented one age class to form the population at time $t+1$. The number of foals in year $t+1$ was determined by multiplying the number of mares at time $t+1$ by age-specific fecundity rates and assigning half the foals to the male population vector and half to the female vector. The basic model, therefore, required 5 user-specified vectors, the structure of the initial population, defined by the number of males and females in each age class, an age-specific fecundity schedule, and age-specific survival schedules for both males and females (Table 1).

Table 1. Values of the 5 user-specified vectors of the wild horse population model.

Age	Initial population		Survival rates		Fecundity rates
	Male	Female	Male	Female	
0	61	61	0.86	0.86	0.00
1	45	45	0.96	0.96	0.00
2	37	37	0.96	0.96	0.36
3	30	30	0.96	0.96	0.56
4	24	24	0.96	0.96	0.66
5	20	20	0.96	0.96	0.72
6	16	16	0.96	0.96	0.75
7	13	13	0.96	0.96	0.76
8	11	11	0.96	0.96	0.77
9	9	9	0.96	0.96	0.77
10	7	7	0.96	0.96	0.77
11	6	6	0.95	0.95	0.76
12	5	5	0.95	0.95	0.76
13	4	4	0.95	0.95	0.75
14	3	3	0.94	0.94	0.74
15	2	2	0.93	0.93	0.73
16	2	2	0.91	0.91	0.72
17	1	1	0.88	0.88	0.71
18	1	1	0.85	0.85	0.69
19	1	1	0.79	0.79	0.67
20	1	1	0.72	0.72	0.65
21	1	1	0.61	0.61	0.63
22	0	0	0.49	0.49	0.60
23	0	0	0.34	0.34	0.58
24	0	0	0.20	0.20	0.54
25	0	0	0.00	0.00	0.51

Figure 1. The basic structure of the population model used in simulations to compare various management alternatives for limiting wild horse populations.



The survival and fecundity schedules used in the model, derived from the demographic studies of Garrott (1990a), are illustrated in Figure 2. These schedules were formulated using models presented by Eberhardt (1985) and represent what we consider median values for wild horse populations. The fecundity schedule is identical to the curve fitted to reproductive data compiled from 1144 mares captured immediately after the foaling season in Nevada (Garrott 1990c). Although age-specific changes in sex ratios suggest differences in survival rates between males and females (Garrott 1990d), direct empirical data are lacking and we chose to use the same schedule for both males and females. The schedule used duplicates the key features of the survivorship curve developed from 11 years of data from the Pryor Mountain herd in Montana (Garrott 1990b). However, slightly more conservative juvenile and adult survival rates were used. The survivorship schedule was converted according to Caughley (1977) to obtain the annual age-specific survival rates required for the population model.

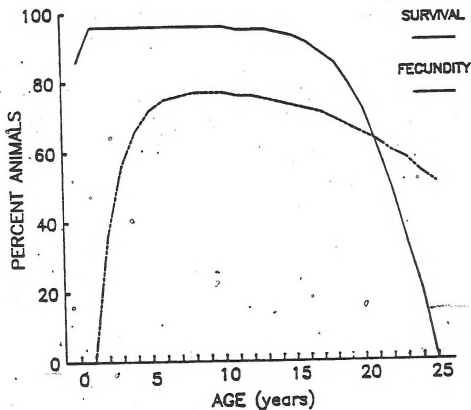
A preliminary simulation was conducted using the fecundity and survival schedules and an arbitrary initial population to determine the stable age distribution. This distribution was then used to calculate the number of horses in each age and sex class for an initial population of 600 animals which was used for all simulations. No density-dependent mechanisms were incorporated into the model, creating a population growing geometrically at a rate of 18% annually. Data presented by Garrott (1990e) indicated that most wild horse herds throughout the West have grown at annual rates of 15-27%, thus the population model mimicked the actual demographic characteristics of wild horse populations.

The Management Goal

Current management programs for wild horses have established a minimum and maximum number of horses to be maintained for each management unit or population. The range of these numbers varies from one administrative unit to the next, however, a general trend is for the maximum number to be approximately double the minimum number. Thus, we established a management goal of maintaining the simulated population between 300 and 600 animals for a period of 20 years. Since the initial population was 600, all simulations included the unselective removal of 300 horses during the first year of the simulation to reduce the population to the minimum. This procedure provided a consistent starting point for all simulations which mimicked typical management programs and facilitated comparison of the various manipulations. The proportion of horses removed or implanted for each management alternative was determined by trial and error. The proportions were varied until the management goal of maintaining the population between 300 and 600 animals for the 20-year simulation

Figure 2. Age-specific survival and fecundity schedules used in the population model. These schedules resulted in a population growing at an annual rate of 18%.

CHARACTERISTICS OF THE SIMULATED POPULATION



was attained while minimizing the number of animals captured and treated.

The Three Management Alternatives

Three management alternatives were simulated, 1) non-selective removals, 2) mare contraception, and 3) selective removals in conjunction with mare contraception. The first management alternative represents the current BLM policy of reducing populations by periodic removal of horses. In the case of the simulated population, the number of horses doubled in 4 years, hence, this management program required the removal of approximately half the animals in the population every 4 years. Since BLM removal programs are not selective, simulations assumed all sex and age classes were reduced proportionally.

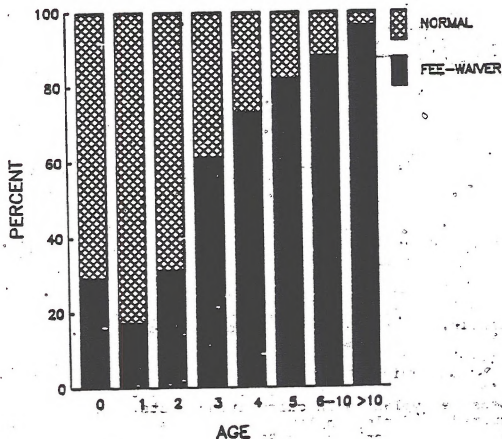
Simulation of the second management alternative, mare contraception, required making a number of decisions on how and when to apply the hormone implants. Available reproductive data indicate that in many populations a substantial proportion of the yearling mares may breed and foaling rates remain relatively high throughout the mare's life span (Wolfe et al. 1989, Garrott 1990c). Because of these high fecundity rates we decided to apply hormone implants proportionately to all age-classes of mares. The implants have been proven effective for 3 years. To maintain a consistent treatment effect over the 20 year simulation period mares were treated at 3 year intervals. Available data indicate that the hormone implants failed to block conception in approximately 15% of treated mares. To compensate for this, an implant efficacy of 85% was incorporated into the model.

A third management alternative involved the selective removal of young horses and treating all other captured mares with implants. This management scenario was developed in response to the strong age-specific preference of participants in the Adopt-A-Horse program. A survey of Adopt-A-Horse applicants conducted by Godfrey and Lawson (1986) found that approximately two-thirds of the potential horse adopters preferred a horse no older than 2 years and only 15% of the applicants wanted a horse over 3 years old. This preference for young animals is reflected in BLM adoption records for 22,625 horses captured between October 1985 and 1989. Figure 3 illustrates the proportion of horses in each age class that were transferred to private care through the regular adoption procedure and the fee-waiver program. The normal adoption procedure prohibits individuals from adopting more than 4 horses per year and assesses a fee of \$125/horse (Bureau of Land Management 1984). The fee-waiver program, implemented in 1984, waves all fees but specifies that the individual must take a minimum of 100 horses in each transaction. This program was designed to dispose of horses which the general public considered undesirable.

Figure 3.

The proportion of horses in each age class that were disposed of through the normal adoption procedure and the fee-waiver program. Data represent 22,625 horses captured between October 1985 and October 1989.

DISPOSAL OF FERAL HORSES USING NORMAL AND FEE-WAIVER PROGRAMS



The rationale behind combining the selective removal of young horses and contraception lies with the fact that most old horses (>3 years) are unadoptable. These animals are responsible for excessive costs of the current management program. Selectively removing only young adoptable animals, therefore, would alleviate this problem significantly. The trade-off, however, is that only approximately half the animals currently removed in reduction programs are in this age class, thus, diminishing the removal program's impact on populations. Part of this lost impact could be recovered by treating all captured mares >3 years old with contraceptive implants and returning them to the range to curb reproduction. The third management alternative, therefore, simulated the removal of 0-3 year old horses every 3 years with all remaining captured mares treated with contraceptive implants before release.

Economic Considerations

A primary criticism of the current management strategy has been its expense. Therefore, we compared estimated costs of the three management programs. Costs can be separated into three basic components, those associated with the capture of horses, expenses incurred in the manufacture and deployment of hormone implants, and the costs of disposing of horses removed from the range. We choose to address these costs on a per horse basis because it was relatively simple to construct the population model to tabulate numbers of animals in each of these categories.

BLM currently uses private contractors to capture horses on a low bid basis. Successful bids have normally ranged from \$50-\$70/horse, however, contracts for capture programs with special requirements (research, complete removals) have occasionally cost as much as \$100/horse. Since none of the three management strategies would require additional work from contractors we choose \$70/horse for all simulations.

Two hormone implants have been developed by the University of Minnesota research team, one using progesterone and ethinylestradiol while the other uses only ethinylestradiol (Plotka et al. this report). The two-hormone implant costs approximately \$180 to manufacture while the implant using only ethinylestradiol costs \$90. Since there was no difference in the performance of the two implants we choose to use the least expensive implant when calculating costs. Additional expenses incurred to deploy implants were estimated at \$10/mare for drugs and surgical supplies and \$28/mare for veterinarian services. The veterinarian costs assume 25 mares a day can be treated with veterinarian services costing \$700/day. Although these costs total \$128/mare, we choose to use \$150/mare when computing costs of implant programs to assure covering any unforeseen expenses.

While determining the costs of capturing horses and treating mares with hormone implants was easily accomplished by consulting people involved in these activities, obtaining similar cost figures for the disposal of captured horses proved impossible. Much of the problem with determining costs of disposing of horses is the complexity of the Adopt-A-Horse program. Capture contractors truck horses to centralized processing facilities in each state where they are aged, inspected for brands, vaccinated, tested for disease, and freeze branded. Costs associated with these activities include veterinarian and brand inspector fees, wrangler wages, and administration and maintenance costs of the facilities. Once horses are processed they are maintained in holding facilities owned by the BLM or privately contracted, with costs per horse of approximately \$2.25/day. Horses may be adopted directly from the holding or processing facilities, but are often trucked to "satellite" adoption facilities located in the more heavily populated states of the upper midwest, Atlantic seaboard, and west coast. All these activities have associated costs which cannot be directly calculated.

As a consequence of our inability to obtain cost estimates for animals placed in the Adopt-A-Horse program we decided to calculate program costs using a range of cost estimates. The clear dichotomy between adoptable and unadoptable horses based on age, in conjunction with the high costs of maintenance of unadopted horses, suggests assigning separate costs figures for disposal of these two categories of horses. We, therefore, used \$150, \$300, and \$450/horse for disposal of the "adoptable" 0-3 year olds. For each of the 3 costs for adoptable horses we used 5 costs for the "unadoptable" horses (>3 year olds) beginning with the same figure as 0-3 year olds and incrementing by \$150.

Incorporating Population Manipulations Into The Model

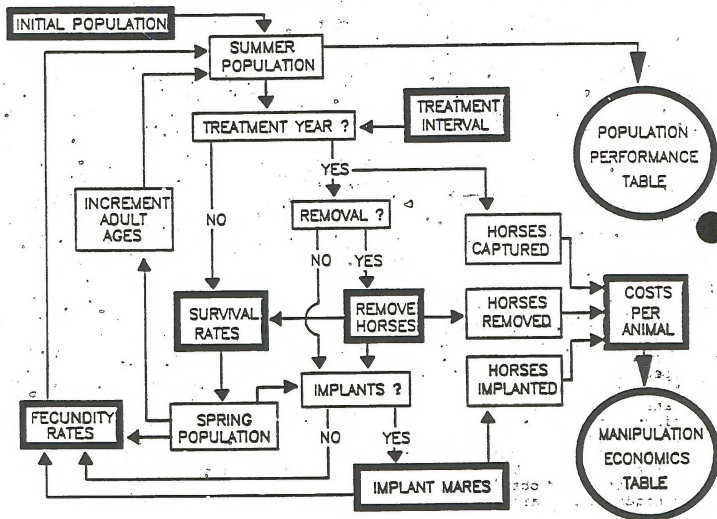
The population model was structured for 3 user specified variables which defined the management program, treatment interval, proportion of mares implanted, and the proportion of horses removed. Both contraceptive and removal treatments were specified for individual age classes to implement age-specific treatments required for the selective removal/contraception management alternative. For each of the 20 years of the simulation, data were tabulated on the number of horses captured, the number of mares treated with implants, and the number of "adoptable" (0-3 year olds) and "unadoptable" (>3 years old) horses removed. These data were then multiplied by the cost/animal to obtain estimates of the total costs of each management scenario (Figure 4).

Demographic Comparisons

Simulations demonstrated that all 3 management strategies could maintain the population between the 300-600 animal goal.

Figure 4. A flow diagram of the model used to compare 3 management alternatives for limiting wild horse populations. User specified components of the model are distinguished by bold boxes and model output by bold circles.

FERAL HORSE POPULATION MODEL



However, the proportion of the population manipulated and the dynamics of the populations were quite divergent. The non-selective removal program manipulated the smallest number of animals, requiring the removal of 47% of the population every 4 years. The mare contraceptive program, in contrast, required manipulating 86% of the population every 3 years; while the selective removal/contraception program was intermediate, requiring manipulation of 53% of the population every 3 years.

The dynamics of the population under the 3 management strategies are illustrated in Figure 5. Nonselective removal was the most disruptive, resulting in dramatic oscillations in horse numbers. The mare contraceptive program reduced the annual growth rate of the population to approximately 2%. This slow growth rate allowed the herd to maintain a relatively steady increase throughout the 20-year simulation and, thus, proved to be the least disruptive management strategy. The selective removal/contraceptive program was less disruptive than nonselective removals, but still resulted in relatively large fluctuations in horse numbers when compared to the program employing only contraception.

Economic Comparisons

Figure 6 summarizes the results of cost calculations for each of the management alternatives using the various cost/horse figures previously described. The general conclusion that can be drawn from these data is that nonselective removal is the most expensive under almost all cost scenarios. The only time that nonselective removal was significantly less expensive than the other 2 management strategies was when removal costs for all age class horses were the same as costs for treating mares with contraception devices (\$150). Differences in costs of the mare contraceptive program and the selective removal/contraceptive program were less pronounced. The selective removal/contraceptive program was slightly less expensive when costs for disposal of horses were low while the mare contraceptive program became the least expensive management alternative as disposal costs increased.

Although the information in Figure 6 provides insights into the relative costs of the various management alternatives, the utility of these economic comparisons is somewhat limited due to the wide range of cost figures used. To estimate the minimum expense associated with disposal of horses, we calculated the average number of days 22,527 horses captured between October 1985 and October 1989 were held in captivity by BLM before care for the animals was assumed by private individuals. Surprisingly, there was little difference in maintenance time for "adoptable" and "unadoptable" horses, with an average of 259 days (Table 2). Using the \$2.25/day/horse charged by BLM contractors, costs for maintenance alone would have averaged \$583/horse.

Figure 5. The simulated dynamics of a population of wild horses subjected to 3 management programs designed to maintain the population between 300 and 600 animals while minimizing the number of horses manipulated.

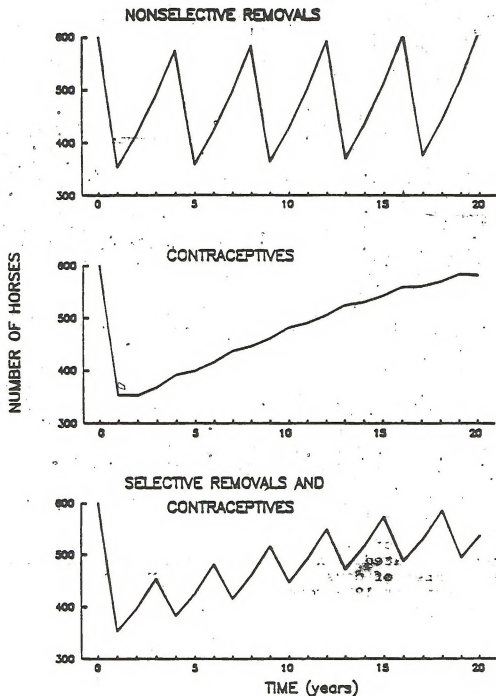
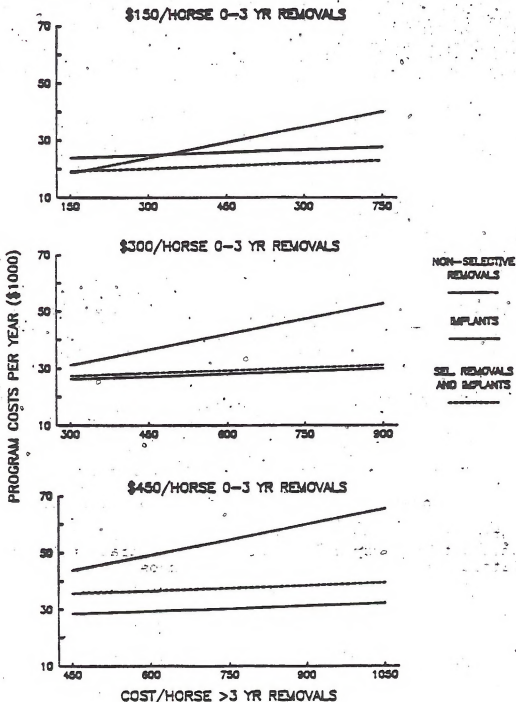


Figure 6.

Comparison of the average annual costs of maintaining a population of wild horses between 300 and 600 animals using 3 management alternatives. Costs of capture and mare contraceptive treatments were fixed at \$70 and \$150/horse, respectively. Costs associated with the disposal of "adoptable" (0-3 year olds) and "unadoptable" (>3 years old) horses were uncertain so a wide range of cost figures were modelled.



These data suggest that the bottom graph in Figure 6 provides the most realistic economic comparisons of the 3 management alternatives. This conclusion is also supported by the a BLM report which estimated that the agency spent approximately \$600 on each horse in the adoption program at the end of fiscal year 1983 (Bureau of Land Management 1984).

Table 2. Average number of days wild horses of various sex and age classes were maintained in captivity by BLM or their contractors before care for the animals was assumed by private individuals.

Sex	Age of horses at time of capture								
	0-3 year olds			>3 year olds			All ages		
	Days	N	SD	Days	N	SD	Days	N	SD
Male	291	6231	206	248	4863	223	272	11094	215
Female	243	7068	166	241	4222	180	242	11290	172
Both	265	13313	187	249	9214	209	259	22527	197

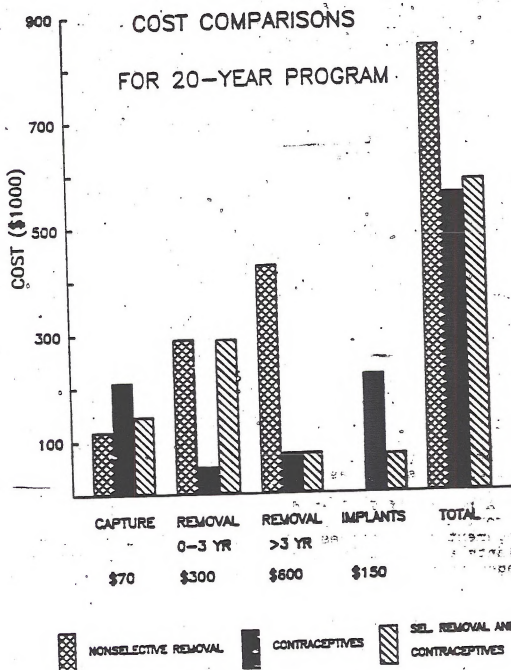
To make more detailed comparisons of costs associated with the various manipulations (capture, contraception, disposal) we used disposal costs of \$300/horse for 0-3 year olds and \$600/horse for >3 year olds. These values are, in all probability, much lower than actual costs of disposal. Using such conservative cost figures, however, does not change the general economic relationships among the various manipulations although the magnitude of the differences is affected. Analysis of the costs incurred for each of the manipulations over the entire 20 year simulation are presented in Figure 7. These data reflect the general manipulation differences between removal and contraceptive management programs. Removal programs expend less money on capture because fewer individuals are manipulated, with most of the program costs attributed to the disposal of the captured horses. Contraceptive programs, in contrast, must manipulate large numbers of animals, hence, major expenses are associated with the capture of horses and contraceptive costs, while little money is required for the disposal of horses.

Conclusions

Each of the three management alternatives simulated in this investigation has both positive and negative attributes. Selection of the most appropriate technique for limiting wild

Figure 7.

A cost breakdown for the various manipulations required to maintain a population of wild horses between 300 and 600 animals using 3 management alternatives. These data are the costs incurred over the entire 20 year simulation period. Costs of \$70/horse for capture, \$150/mare for contraceptive implants, \$300/horse for disposal of 0-3 year olds, and \$600/horse for >3 year olds.



horse populations depends on which aspects of the management program are considered the most important. To facilitate comparisons among the three management alternatives, we generated a table summarizing seven attributes for each alternative that addresses the major points of contention in the current management program (Table 3).

Table 3. Comparisons of various attributes of 3 management alternatives for maintaining a population of wild horses between 300 and 600 animals for a period of 20 years.

Management Attribute	Management Alternatives		
	Nonselective removals	Mare Contraception	Sel. removals &
Population disruption	High	Low	Intermediate
Number horses captured	1695	3023	2101
Number horses implanted	0	1491	488
Number horses removed	1695	300	1100
Horse range years	9453	9567	9577
Horse maintenance years	1203	213	781
Costs per year	\$42100	\$28200	\$29400

Population disruption, has been discussed earlier in this paper and refers to oscillations in horse numbers induced by the management program. The next three attributes, representing manipulation characteristics of each alternative, summarize the number of horses which must be captured, implanted, and removed. Horse range years was calculated as the summation of the number of horses in the population each year over the 20 year simulation. This attribute, therefore, provides an index of the total forage requirements or AUMs which would need to be allocated for horses. Horse maintenance years was calculated by multiplying the total number of horses removed by the average time animals were maintained in BLM holding facilities. Program costs are presented as the average annual cost.

A review of Table 3 demonstrates the trade-offs and compromises which are necessary when selecting among the three management alternatives. In general, the use of contraceptive implants appears to be a viable alternative to the current management program based on nonselective removal of horses. The simulations indicate that contraception programs would significantly reduce the number of horses which would have to be removed and thus alleviate the problem of maintenance and disposal of excess horses. Further, a contraceptive program would minimize population fluctuations and reduce management

costs to at least half that of the nonselective removal program. The major disadvantage of a contraceptive program is the large number of horses which must be captured due to the necessity of capturing both sexes to treat the mares. This drawback, however, would not appear to be overtly detrimental because capturing horses is relatively easy and inexpensive and probably subjects the animals to less stress than long-term captivity.

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